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14. ABSTRACT

This research effort develops a generalized decision support system (DSS) to assist contracting career field managers in making recruiting and retention decisions. The DSS focuses on the skill level inventories of the contracting enlisted force. The interest in this research was identified by contracting career field managers due to the recent negative trends in recruitment and retention and the lack of analytical tools available. To accomplish this objective, manpower models were developed using a combination of techniques gathered through interviews with Army and Air Force analysts and a literature review focusing on manpower modeling.

The models developed in this study are intended to assist career field managers in recruiting and retaining the correct number and skill level mix of personnel in the contracting career field. The models are generalized enough to serve as a DSS for other Air Force Specialty Codes (AFSC) with minimal revision.

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A GENERALIZED DECISION SUPPORT SYSTEM

FOR THE CONTRACTING CAREER FIELD

THESIS

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AFIT/GAQ/ENS/02-02

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY

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AFIT/GAQ/ENS/02-02

A GENERALIZED DECISION SUPPORT SYSTEM FOR THE CONTRACTING CAREER FIELD

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A GENERALIZED DECISION SUPPORT SYSTEM

FOR THE CONTRACTING CAREER FIELD

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Larry D. Mercier Jr.

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AFIT/GAQ/ENS/02-02

Abstract

This research effort develops a generalized Decision Support System (DSS) to assist contracting career field managers in making recruiting and retention decisions. The DSS focuses on the skill level inventories of the contracting enlisted force. The interest in this research was identified by contracting career field managers due to the recent negative trends in recruitment and retention and the lack of analytical tools available. To accomplish this objective, manpower models were developed using a combination of techniques gathered through interviews with Army and Air Force manpower analysts and a literature review focusing on manpower modeling.

The models developed in this study are intended to assist career field managers in recruiting and retaining the right number and skill level mix of personnel in the contracting career field. The models are generalized enough to serve as a DSS for other Air Force Specialty Codes (AFSC) with minimal revision.

Note: The three manpower models that make up the DSS are on the CD attached to the inside cover of this thesis. The software requirements are listed on the DTIC Form 530 at the end of this document just preceding the SF Form 298.

A GENERALIZED DECISION SUPPORT SYSTEM FOR THE CONTRACTING CAREER FIELD

I. Introduction

General Issue

In recent years, the United States Air Force has been besieged by recruiting and retention problems. "We have been through these problems before", said Carol A. DiBattiste, former undersecretary of the Air Force, who served in recruiting both as an enlisted member and an officer before retiring in 1991. "The trouble this time is that we have retention and recruiting problems hitting us at the same time" (Callander, 2000:64).

The retention and recruitment problems are partly attributed to the booming economy and the increasing number of job opportunities available in the civilian sector. "When we have a booming economy," said DiBattiste, "it puts extra pressure on the Air Force, both to recruit and to retain. It pulls people away from the service and creates recruiting difficulties because young people have many more opportunities" (Callander, 2000:66). Recent reductions in force, changes to military benefits, and increases in Operation Tempo (OPTEMPO) have also added to these problems. The enlisted force in each of the military departments has been affected the most because of the large pay differences between what they currently earn in the military and what they can potentially earn in the civilian sector. The Department of Defense has been working diligently

devising incentives to improve recruiting and retention in all branches of the United States military.

Personnel shortages have caused many concerns for the Department of Defense as a whole, each individual military service, and each career field or specialty code within those departments. The two greatest concerns of Air Force contracting career field managers are interrelated and most likely shared by all career fields in all military departments. First, will there be enough people in the career field to carry out the mission? Second, will the skill level of these people match the skill level requirements? The second question is the most important because, even if there are enough people, they will be unable to carry out the mission unless they have the proper mix of skill levels. If everyone in the career field were at the apprentice level, they would not have the skill, experience and training necessary to get the job done. Former Air Force Chief of Staff General Michael Ryan stated, "So, it's not just the numbers of people that you have to have in a particular skill, but the quality of those who are in that skill matched against the requirements we need in our force to be able to do the things we have promised the nation we can do" (Airmen 1998:8). For these reasons, career field managers must be aware of their manning and skill level requirements in order to properly match the personnel to critical positions to successfully carry out the mission.

In many of the career fields in the Air Force the issue is not just the number of people being recruited, but also the number of people electing to get out after their first, second and retirement eligible enlistments. "Equally worrisome, enlisted retention rates have fallen off. USAF's aim is to retain 55 percent of first termers, 75 percent of second termers, and 95 percent of career-enlisted troops. For 1999, however, the first-term rate

fell to 49 percent, second-term rate to 69 percent, and career rate to 91 percent" (Callander, 2000:66). The opportunities in the civilian sector are attracting many of the skilled enlisted members of the Air Force. This problem is magnified by the lack of incentives offered to retain these individuals. Once an enlisted member enters the higher grades and has gained the requisite skills and experience that make him or her a valuable asset, the opportunities for career progression slow and the raises are not large enough to compete with the pay being offered in civilian equivalent positions. This should be when these highly skilled individuals are offered more opportunities and higher pay. Another problem is that once these skilled individuals reach the 20-year point in their career, they are eligible to retire and receive 50 percent of their pay and pursue a more lucrative, compatible position in the civilian sector or DoD.

Senior leadership in the Air Force, as well as the other military services, has recognized these recruitment and retention problems and is giving them the attention they deserve. Former Chief of Staff General Michael Ryan commented, "We have concerns about our readiness from an individual standpoint and the loss of expertise. Expertise is what we need to maintain readiness" (Airmen, 1998:8). Senior military leadership along with Congress has made huge strides in the last couple of years by re-instituting some of the benefits, increasing raises to make pay more commensurate with the civilian sector, and raising the military's quality of life.

Even with the improvements made, we are a long way from solving all of the recruiting and retention issues. In the meantime, each career field must acquire and retain at least enough people to accomplish their part of the Air Force mission. In order to determine whether or not the career field has or will have enough qualified people to

accomplish the mission, career field managers must closely monitor the current manpower requirements and predict the future state of manpower inventories. Having a decision support system with appropriate forecasting and modeling tools available would significantly improve a career field manager's ability to maintain manpower inventories at the required levels.

All branches of service, as well as each career field or specialty code under each branch, has offices within them that are responsible for forecasting manpower needs. The Air Force Personnel Operations Agency, Directorate of Personnel Analysis for the Enlisted Force (AFPOA/DPY) has many tools available to determine the approximate number of people to recruit into the Air Force as a whole as well as each career field. These models are very helpful to career field managers in determining recruitment numbers. However, these tools do not tell career field managers the current and future state of the career field's skill level inventory. The forecasting office deals more with large-scale, generalized models to forecast manpower needs. They do not have the resources to develop multiple models tailored to meet each career field's manager's individual needs.

The contracting career field in the Air Force has been especially vulnerable to manpower retention issues. The training and experience each contracting professional gains in the Air Force is a valuable commodity in the civilian sector and among Department of Defense (DoD) contractors. Many DoD contractors are willing to pay high salaries to acquire the knowledge and experience contracting professional's gain in the Air Force.

Background

The Air Force, along with all military departments, is hierarchically organized. This type of structure has served the military well by providing the framework required to support these large organizations. This structure is further supported by a grade and rank system that promotes personnel from within the organization. This grade and rank system has been around since inception. This system was designed to provide discipline, organization and structure to accomplish a wartime mission. It was designed to distinguish between those that make the decisions and those that would carry them out. Today, many civilian organizations are employing a more horizontal structure with less management and more workers. "Now many organizations are seeking greater flexibility and the ability to respond more quickly to their environment by adopting flatter structures. These flat structures are characterized by few levels of management; broad, wide spans of management; and fewer rules and regulations" (Griffen, 1999:57). These flatter organizational structures also give workers more authority to make the necessary decisions to get the job done. This process of granting decision-making power to the lower levels of the organization is called empowerment. Empowerment is also being adopted in the military but the difference is that the military has maintained its hierarchical structure. The reason the military has maintained its hierarchical structure is due to its wartime mission. In a wartime scenario it is imperative that command and control remain intact in order to run a successful campaign against enemy forces.

In the Air Force, the shift toward empowerment has pushed down decision-making allowing lower level management to make decisions dealing with their level of the organization. This has allowed higher levels of management to concentrate on larger

issues dealing with the strategic direction of the organization or the command. Empowerment has also increased the emphasis on training and job knowledge. The reason for this increased emphasis is to ensure that the people being empowered have the required skills to make the right decisions and perform at the correct skill level. Skill level is a term used within each Air Force career field to signify the amount of training and experience a person in the career field has attained. Enlisted personnel progress from the initial skill level 1 to skill level 3, skill level 5, skill level 7, and, possibly, skill level 9. Only a few enlisted ever reach the 9 skill level. This final level is held for those that have demonstrated exceptional abilities not only in their career field but also in the Air Force in general.

Career field managers consider the 7-skill level the most critical to mission success. The 7-level airmen have the experience and knowledge required to train others in the career field, to run and manage a contracting office, and, most importantly, the ability to run a one or two person operation, characteristic of today's contingency operations. These 7-level attributes make it imperative for career field managers to maintain at least the minimum number of 7-level airmen to accomplish both the stateside and contingency missions. The only way to assure the proper number of 7-levels is to have tools available that will make career field managers aware of future shortages so they can take appropriate, corrective action.

Problem Statement:

The contracting career field in the Air Force is facing challenging manning issues within its enlisted force. Over the last decade the career field has been hit with a

reduction in force and an increase in OPTEMPO. This, coupled with an increase in job opportunities for contracting professionals in the civilian sector, has caused some concern among those responsible for managing the career field. Over the last couple of years, the number of first term and retirement eligible airmen leaving the Air Force has increased dramatically. These drastic changes have increased the importance of monitoring manning levels in the career field, especially the skill level mix within the career field.

The increased outflow of career airmen eligible to retire has caused a concern in the availability of 7-skill level personnel. The 7-skill level is key to both the stateside and contingency missions of the contracting career field. These 7-skill level airmen provide the force with the experience and skills necessary to carry out the contracting mission; to train personnel, provide job knowledge to a unit and successfully conduct one or two person contingency operations. Without the minimum number of personnel in this skill level, the career field and the contracting mission in the Air Force will surely suffer.

According to contracting career field managers at the Office of the Secretary of the Air Force for Acquisition (SAF/AQC) one way they are attempting to counter shortfalls in skill level manning is to change the contracting career field-training plan. The new career field-training plan will be implemented in fiscal year 2002. This plan has slightly shortened the training time required to progress from one skill level to the next, but has not decreased the number of training objectives that must be mastered before being awarded the next skill level. Career field managers are hoping this change will help increase the number of 7-level airmen in the career field but not to the detriment of training and experience. The projection model being developed for this thesis is based on

this new training plan and should illustrate the effect it will have on the career field's skill level mix over the next twenty fiscal years.

The problem facing contracting career field managers is that the utilities used by the Air Force Forecasting Office do not specifically address career field manning by skill level. As previously mentioned, the office uses larger, more generalized models to forecast manpower needs. The systems they use are based on grade and rank. The problem with focusing on grade and rank is that the career field may appear to be fully manned because they have enough people in each rank and grade but in reality they are under manned in certain skill levels. This is especially apparent in the contracting career field where the majority of accessions are retrainees, which means they have higher ranks than pipeline recruits but are starting over at skill level 1 in the contracting career field.

The large number of retrainees recruited into the contracting career field each year creates potential manning problems. Retrainees transfer into the career field from other career fields. These new retrainees possess the rank to hold certain positions but not the skill level. Currently, the number of yearly accessions is approximately 180, comprised of 120 retrainees and 60 pipeline personnel. Pipeline personnel, or direct accessions are those that enter the career field directly from basic training. The 120 retrainees enter the career field with ranks ranging from Airmen (AMN) to Master Sergeant (MSgt) with the majority being Staff Sergeant's (SSgt) and Technical Sergeant's (TSgt) and with time in service (TIS) ranging from 4 years to 16 years with the majority being between 8 and 12 years TIS. The current personnel system assigns these SSgt's, TSgt's, and MSgt's to 5- and 7-level positions based on their rank when in reality they are new to the career field and may only be holding a 1- or 3-skill level in contracting. One of the manning

problems with pipeline personnel centers on SSgt's awarded a 7-skill level but not considered a 7-skill by AFPC until they are promoted to TSgt.

In order to establish a more detailed estimate of the skill level inventory in the contracting career field, this research develops a Markovian based prediction model based on skill level. The Markovian process tracks the flow of personnel through an organization. "The "flow" of personnel through a system may be thought of as movement from category (e.g., grade, year of service, occupational specialty) to category. The utility of the concept depends upon the definition of meaningful subsets of the population, referred to as "states," from and into which all movement occurs with statistical regularity" (Merck and Hall, 1971:5). The model focuses on fiscal year, skill level, and TIS. It provides a detailed assessment of the current and future skill level manning levels in the career field. The model also identifies current and future shortfalls in each skill level and, most importantly, the 7-skill level. The number of personnel in each skill level generated from this Markovian process could be used as input for a linear programming model indicating what positions should be filled and which should be left vacant based on mission related priorities. The Markovian based projection model is incorporated into a spreadsheet model that is easy to manipulate and analyze. This spreadsheet model is also used as input for a stochastic and an optimization model. The stochastic model determines the effects that variable loss rates have on skill level inventories and analyzes the risk associated with each possible inventory outcome. The optimization model determines the best mix of pipeline and retrainees to recruit into the career field each year to maintain mission capability. These models make up a generalized decision support system for contracting career field managers to use in

identifying problems with and support changes to current recruiting and retention programs. *(The three manpower models that make up the DSS are on the CD attached to the inside cover of this thesis. The software requirements are listed on the DTIC Form 530 at the end of this document just preceding the SF Form 298.)*

Research Objectives

The objective of this research effort is to develop a decision support system to assist contracting career field managers in making recruitment and retention decisions. The DSS will include a Markovian based projection model to display current and future skill level manning, taking into account pipeline and retrainees entering the career field, time in service, loss rates, training time lines, and the time it takes to attain certain grades and ranks. It will also include a stochastic model, which will enable career field mangers to analyze the effects of variable loss rates and identify the probabilities associated with each possible inventory outcome. Finally, it will include an optimization model to determine the right number and best mix of pipeline and retrainees to recruit each year in order to maintain or exceed the minimum manning requirements.

Summary

The Air Force is facing some challenging times with an increasing OPTEMPO and decreasing recruiting and retention rates. These problems have been readily apparent and may even be magnified in the contracting career field. Unless something is done to motivate people to stay in the Air Force and in the contracting career field the problem with retention is likely to continue and may worsen. This type of uncertainty in the manpower structure of the career field makes it imperative that career managers and

decision makers have as much information as possible to make accurate, strategic decisions. This information helps decide how many and what mix of recruits and retrainees will be required each year to maintain the required inventory levels as well as the required skill level mix to accomplish the contracting career field's mission. The Air Force Forecasting Office currently provides the contracting career field with a forecast of the number of personnel required to maintain its minimum manning levels. This thesis provides career field managers with a generalized decision support system to help determine skill level requirements and how to tailor their retention and recruitment approach to meet those requirements.

The next several chapters of this thesis discuss the development of the models that make up the decision support system. The DSS will provide contracting career field managers with critical information on career field manning based on skill levels. This type of information is very important in determining if there are enough skilled personnel to handle each skill level requirement. Chapter 2 examines personnel modeling, in general, including many different approaches to personnel modeling. It concludes with a discussion of the Markovian and optimization approaches being considered in this research effort. Chapter 3 covers the methodology for model implementation in detail. Chapter 4 analyzes the results obtained from the models. Finally, Chapter 5 discusses recommendations based on the results documented in the preceding chapter.

II. Literature Review

Introduction

Personnel modeling deals with designing and developing manpower models to monitor and forecast personnel inventories within an organization. These models provide valuable information to improve recruitment and retention decisions. The manpower information generated by these models assists management in balancing personnel inventories to accomplish the organization's mission.

Manpower modeling is used throughout the Department of Defense. Most military organizations use several different models to serve several different purposes. Military departments are large hierarchical organizations requiring large numbers of people to accomplish their mission. The information gathered through manpower modeling is imperative to the successful accomplishment of that mission. The Department of Defense relies greatly on manpower information to determine recruitment and retention targets.

Manpower Modeling Techniques

There are many different modeling techniques in existence. Manpower modeling techniques used in the military include: Markovian processes, goal programming, network flow modeling, linear programming and optimization. Organizations must match their requirements with the limits and capabilities of each technique in order to select the best technique or techniques for its modeling needs. Considerations in selecting the appropriate modeling approach include: the type of organization, the type and accuracy of information required, and the resources available.

Projection Models (Markov Models)

A Markovian or projection model is used to track and record personnel progression within an organization. Saul Gass states, "Markov models are used to estimate new hires, separations, retirements, training requirements, shortages by class and steady state inventories" (Gass, 1991:67). The information generated by Markovian models is used to predict future manpower requirements. Gass, an expert in manpower modeling, is well versed in the Markovian process, the assumptions associated with that process and how to apply the process to military manpower modeling. The Markov process is a significant part of this research effort and provides the framework for all three models being developed.

Markov models are known as transition or predictive models. Gass states, "Transition rate models are used to forecast personnel inventory levels based on known transition rates" (Gass, 1991:66). In the Markov process personnel are aggregated into groups or states using identifiable characteristics over a certain planning timeline. The transition rates establish the flow of personnel from one state to the next. "Each person is a member of one and only one class, but a person can change classes based on transition assumptions" (Gass, 1991:66).

Merck and Hall provide the following explanation of the Markovian process:

> The flow of personnel through a system may be thought of as movement from category (e.g., grade, year of service, occupational specialty) to category. The utility of the concept depends upon the definition of meaningful subsets of the population, referred to as 'states,' from and into which all movement occurs with statistical regularity. In general models of transitional flows, movement is possible from each state to any other, including the state of origin. The measurement of transitional flows may be defined in terms of the probability of movement from one state to any other. (Merck and Hall, 1971:5)

This provides an excellent description of the Markovian model developed for this research effort with the exception of a state being allowed to transition back to the state of origin.

The design of the Markov process is well suited for the skill level inventories being addressed in this thesis. Subjects are associated with a specific state according to their rank, skill level and TIS and each state is associated with known transition rates.

The following assumptions are associated with the Markov process.

1. Each individual is governed by the Markov process and only the last state occupied determines the individual's next state.
2. The same Markov process applies to all individuals.
3. All individuals behave independently.

In addition to the aforementioned assumptions, personnel in a Markov process must transition forward to the same state in the next period or to the next higher state in the next period. Transitions do not occur backwards. This leads to another issue known as conservation of flow, which requires the flow of personnel transitioning into a certain state to equal the flow that transitions out of that state. Violating any of these assumptions or requirements may lead to erroneous information and flawed decision-making.

Gass provides a visual representation of the Markov process in a military manpower scenario using the node and arc structure depicted below. The node and arc structure displays the transitions taking place between states.

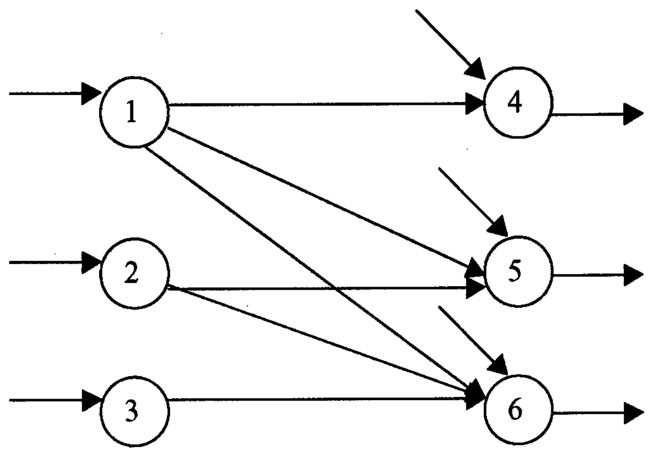


Figure 1. Transition Rate Model Network Representation

Figure 1 represents a network with nodes representing states by time period and arcs representing transitions from one state to another. In the above example there are six states and transitions are made to only one of the three states in the next time period. The total flow into a node must be equal to the total flow out of that node this is known as conservation of flow. Conservation of flow is used to maintain accountability throughout the model. (Gass, 1991)

J.W. Merck and Kathleen Hall have developed Markovian models that track personnel movement throughout the United States Air Force personnel system. In an article discussing their modeling experiences they reveal problems encountered while applying a Markovian approach.

> The lack of statistics on transitional behavior is a result of 1) the difficulty of obtaining information on changes of status using personnel records designed on the basis of traditional inventory concepts; and 2) the difficulty of comprehending the net impact and significance of a huge number of transition paths upon future distributions of the population. (Merck and Hall, 1971:Preface)

Saul Gass documents similar problems. "For large personnel systems, there is some difficulty in collecting transition rates, and the steady-state forecasts many not be

accurate enough as the transition rates do change over time" (Gass, 1991:67). These data problems were not an issue in this research effort because of the focused scope of these models and the improvements made in data collection over the last few decades has been significant.

Merck and Hall also describe the benefits of Markov models, which still hold true today.

> The model and computing procedures used in the Markov process permit personnel managers 1) to create an information system that captures much of the social and geographic mobility that military personnel continually undergo; 2) to completely and systematically compute the rates with which these movements occur; 3) to estimate the effects that these movements are likely to have in the future; and 4) to estimate the impact that management-policy-generated alterations of these rates of movement have upon the future of the personnel system in question. (Merck and Hall, 1971:7)

These benefits, particularly 3 and 4, closely resemble the objectives of this research effort.

Merck and Hall support and encourage the use of Markovian models in military applications.

> Military personnel systems have characteristics that make them peculiarly susceptible to analysis by Markovian models: 1) entries into military systems are made at specific low-level entry points in the hierarchy; 2) recruits (either officer or enlisted) are essentially undifferentiated, with specialization occurring as a result of training and experience that takes place after entry into military life; and 3) because breaks in service are rarely allowed, the process of movement through the military personnel system becomes a close analogy to an actuarial, life/death, model of life expectancy. (Merck and Hall, 1971:5)

Graham Leeson also supports the Markovian approach to manpower planning. He states, "Markovian chain models have been extensively advocated for the description

of transitions in hierarchical manpower systems. Furthermore, this type of model is able to provide measures for the description of the experience of the system at both the individual level and the system level" (Leeson, 1984:933). Leeson is an advocate for the Markovian approach but his interests lie in the qualitative aspects of recruitment and retention policies and how such policies influence desired internal structures. Leeson is a valuable resource for researchers studying the qualitative aspects of recruitment and retention.

The Markov process provides unparalleled support for the enlisted manpower models being designed in this thesis. Markov models provide meaningful information to be used in recruitment and retention decisions as well as pertinent information regarding personnel progression in the contracting career field. The Markovian model developed for this research effort displays manning shortages by skill level and steady-state inventories within those skill levels. The Markov process is used as input for the optimization model providing career field managers with a best possible recruitment strategy given their resource constraints.

Goal Programming Problems

Goal Programming models are very effective in solving large-scale manpower problems. R.W. Collins states, "The needs of managing a multi-attribute pool of personnel over a long-term horizon has led to a number of linear-programming based approaches for evaluating policy options" (Collins et al, 1983:44). Gass adds, "The formulation of a linear goal-programming model assumes that all problem constraints serve as goals to be attained simultaneously as 'best' possible. Here, best is interpreted as a satisfying or compromise solution" (Gass, 1986:779). Gass also explains the

importance of applying weights to variables in the model to attain the desired information based on priorities. He uses Army manpower modeling to explain the goal programming approach. "A case in point is U.S. Army personnel models that are designed to determine the number of soldiers, by grade, skill and or years-of-service, that meet manpower goals (targets) over seven to 20-year planning horizon" (Gass, 1986:780). This design is very similar to the optimization model being developed for this research effort with the exception of model scope.

The optimization model developed for this thesis focuses on minimizing manning shortages in each skill level by using deviational variables and weights. "Goal programming solution techniques choose the values of the decision variables such that deviations from the goals are minimized. If it is not possible to achieve all goals, goal programming attempts to satisfy the goals in order of priority" (Wu and Coppin, 1981:358). The goal programming approach is ideal for this research effort because of its ability to handle conflicting goals. The goal programming approach allows the model to arrive at the best possible solution in light of all constraints, weights and conflicting goals. "Goal programming entails an explicit consideration of goals and how closely they can be achieved and the various priorities associated with the different goals" (Wu and Coppin, 1981:360).

Minimax is a technique used in goal programming that minimizes the maximum deviation from any and all goals. This technique was chosen to minimize the maximum deviations from all skill level goals as opposed to minimizing the sum of the weighted deviations. Minimizing the sum of the weighted deviations could result in some skill levels being over manned while others are left extremely undermanned. Minimizing the

maximum deviations from all skill level goals allows for a more balanced solution. Another reason this technique was chosen is its ability to handle hard constraints. The model developed in this thesis contains two hard constraints that pertain to the number of pipeline accessions and retrainees allowed to enter the career field in a single year.

When applying goal-programming techniques in manpower models there are many issues to consider, one of which is determining weights and priorities. This determination is difficult when dealing with large-scale linear goal programs. Gass explains how to create different levels to study the impact of each component and how each component interacts with other components. He sets up three levels in a hierarchical format. The first level is the personnel program as a whole. The second level is the total end strength for each of the years being modeled. The third level is the goals for each year. The goals included skill targets, promotion targets, loss targets, and gain targets. He claims that setting the problem up in this manner simplifies the process of selecting rates for elements in level 2 and level 3. Level 1 illustrates the overall focus or objective of the model. Level 2 is analyzed and weights are assigned in a matrix format based on the priority for year-end strength. The same process is completed in level 3. The final step is to calculate the comparison matrices to determine the weights to use in each element. Gass supports the utility of this approach and how effortless it is for managers to make adjustments to these matrices when policy or other factors change the priorities of the model. (Gass, 1986)

The matrix system was developed to handle problems with a larger number of weights and priorities, like many of the military manpower models used today. More focused models, such as the models being developed in this thesis, do not require such

elaborate systems. For these types of models it is more efficient to have the user determine the weights and priorities based on his or her experience, knowledge, goals and priorities. Gass supports this point by stating, "We take the position that the model user and problem formulator have enough information to be able to select a set of weights, or are able to provide trade-off information with which an acceptable set of weights can be determined" (Gass, 1986:780).

Other alternatives for solving goal-programming models include special algorithms or advanced network codes. Each of these alternatives focuses on speed and cost savings. Over the last few decades the major focus of manpower modeling has been developing faster more efficient models. This focus has helped manpower offices deal with the overwhelming growth in the last decade. Using the antiquated systems of the past poses significant problems for today's larger organizations, especially the United States military. The new approaches allow analysts to develop models, which provide instantaneous information to the user at a much lower cost.

Agha Iqbal Ali, Tom Blanco and Ben Buclatin discuss two alternatives for solving goal network programs. One method is the sequential linear goal-programming (SLGP) algorithm and the other is the goal network simplex algorithm. "It is desirable to have an algorithm that runs in only a few seconds as opposed to several minutes for a standard commercial linear programming solver" (Ali et al., 1997:192). The principle difference between these two algorithms is that the goal network simplex algorithm preserves the network structure and allows for simultaneous pricing of the objectives. The intention of both methods is to locate an optimal solution faster and cheaper while taking into account all constraints and multiple objectives. Ali, Blanco, and Buclatin

note, "The goal network simplex algorithm is exactly the same as the network simplex algorithm except for a pricing rule that employs reduced costs for each of the criteria in the multi-criteria objective simultaneously" (Ali et al., 1997:193).

W. L. Price has performed similar work using goal programming manpower models. His approach deals with importing advanced network codes into the models, again, to make the models faster and more efficient. Improving the speed and efficiency of manpower models is a recurring theme throughout today's modeling literature.

> The goal programming structure can be preserved in most cases through careful definition of the flow-cost function and through the use of multiple arcs in the network. This latter feature is made practical through the use of advanced network codes, such as GNET, that are now available. Solution times and costs are significantly lower than those obtained with the original goal programming formulation through the use of generalized linear programming codes. (Price, 1978:1233)

The basic premise behind GNET and other network codes is to simplify the model. The set up required for these network codes appears more complex because they require multiple arcs, splitting nodes, and summing the flows of the various arcs, but, in reality, the model is much faster and more efficient. There is software available to perform these additional requirements effortlessly. "It is the large reduction in cost that is the principle interesting feature of the GNET formulation" (Price, 1978:1239). The models being developed for this thesis effort do not warrant these types of algorithms and network codes. If the models are expanded in the future these techniques should be looked at more closely to improve model speed and efficiency.

Optimization Models (Network Flow Problems)

In an article, addressing multi-period, multi-criteria optimization for manpower planning, Joe Silverman discusses the use of optimization models for manpower

planning, the structure of those models, the formulation of those models and the Tchebycheff method. Optimization modeling was derived from goal programming and is a technique capable of manipulating multiple objectives, which is a critical aspect of recruitment and accession planning. Silverman states, "In accession planning, we are concerned with the selection of a recruitment schedule over multiple time periods, which best meets goals pertaining to promotion opportunity, salary expenditures, desired levels of experience in the workforce, and requirements for manpower in each of the planning periods" (Silverman et al., 1998:160).

The problem addressed in the article is classified as a multi-criteria trajectory optimization problem because (1) the problem spans multiple time periods, (2) the user wants solutions at the end of each time period and (3) there are goals for each objective in each time period. The term trajectory refers to a path of goals for each of the time periods. This set-up is similar to a MINIMAX goal-programming problem where the objective to is to minimize the maximize deviations between the trajectory (goals) and the actual numbers.

In the article scenario, Silverman chose the Tchebycheff method to solve the multi-criteria trajectory problem. The Tchebycheff method is designed for problems with a large number of variables and weights. In these types of problems it is very difficult to accurately assign weights because of the large number of objectives. The Tchebycheff method eliminates the need for selecting weights by solving the problem multiple times within the set of constraints and allowing the user to select the best feasible solution. Silverman explains, "The appeal of the Tchebycheff approach is that it generates multiple

solution candidates at each iteration, does not ask the user to specify weights, and enables one to converge to non-extreme final solutions" (Silverman et al., 1998:161).

The optimization approach used in this article parallels the Optimization model developed in this research effort. The information generated by this model provides contracting career field managers with critical information to use in selecting a recruiting strategy. This strategy considers all accessions, attritions, and progressions. The personnel analysts and the governing focus of their research effort will determine weight selection.

A.J. Figueira is another expert in manpower modeling arena. Figueria supports the use of mathematical programming heuristics in a multi-criteria network flow context. Figueira addresses the problem of attempting to locate an optimal solution when the model contains conflicting criteria. Figueira and other colleagues have developed a heuristic that allows models to locate a feasible solution that is acceptable to the conflicting criteria.

> We propose a heuristic method based on Lagrangean duality and sub gradient techniques, called SG-CPLEX, implemented with CPLEX routines to search for feasible points in the neighborhood of the satisfying point. This heuristic method exploits the combinatorial structure of network flow problems in order to find certain feasible points in the indifference area. (Figuira, et al., 1998:878)

It is important to note that methods are available to deal with conflicting criteria.

Other algorithms have been developed to solve network flow problems with side constraints. Mathies and Mevert explain how using certain network optimization algorithms can translate into a more efficient and much faster model than using general linear programming optimizers. "Solving the same problem with general linear

programming optimizer would take at least 100 times longer" (Mathies and Mevert, 1998:745). Mathies and Mevert explain how many real world problems contain additional constraints that destroy the network structure of the coefficient matrix making it necessary to solve the problem using the general linear programming approach. Mathies and Mervert discuss ways of handling such side constraints to make the model more efficient through the use of a network algorithm. They discuss three such approaches, which combine the advantages of both network algorithms and general linear programming.

Army Modeling

The Army uses many different types of modeling techniques to satisfy various modeling requirements. Henry S. Weigel and Steven P. Wilcox discuss the Army's various modeling approaches. They explain modeling techniques used, the requirements being met by those techniques and the advantages and disadvantages of each technique. "The Army's enlisted personnel decision support system combines a variety of modeling techniques, such as goal programming, network models, linear programming, and Markov-type inventory projection, with a management information system to support analysis of personnel planning issues" (Weigel and Wilcox, 1993:281). The Army enlisted models include: Enlisted Loss Inventory Model (ELIM), Computation of Manpower Programs using Linear Programming (COMPLIP) model, Military Occupational Specialty Level System (MOSLS), Unit Level System (ULS). These models use one or a combination of techniques to meet the Army's objectives.

The Army's manpower models are designed as a hierarchy of systems. Weigel and Wilcox explain, "It is defined here as the process of representing a large problem in the form of a sequence of linked models. Each echelon of the hierarchy provides certain pre-defined constraints for the next lower echelon" (Weigel and Wilcox, 1993:282). The hierarchical structure helps separate each level so analysts can focus their models on the issues relating to that level. Each subsequent level uses the constraints of the levels above. This sequential approach is necessary because the modeling techniques and computer technology available today could not handle the combined requirements of all the sequential models at once.

The ELIM-COMPLIP is a model that accesses the number of accessions, losses, reenlistments and strength by month. "The particular focus of ELIM-COMPLIP is on accuracy of projections and flexibility of policy implementation at the aggregate level" (Weigel and Wilcox, 1993:282). The modeling techniques used for the ELIM-COMPLIP model is inventory projection coupled with linear programming formulation. "The objective of the LP optimization is to determine the accessions each month such that the sum of the absolute values of the deviations of the projected operating strengths from the strength targets is minimized" (Weigel and Wilcox, 1993:282).

The MOLS model is similar to the ELIM-COMPLIP except it focuses on the MOS and grade level of detail, using the aggregate quantities generated by ELIM-COMPLIP. The MOLS model is set up in a two-stage hierarchical system of its own. The first model, known as the T-Model analyzes training time groups and grades.

> The model is a multi-time-period linear optimization (LP with a large embedded network) model using strengths targets at the appropriate level of detail that are consistent with the targets used in ELIM-COMPLIP. The

> objective of the model is to determine such decision variables as trainee graduates, promotions, and reclassifications so as to project strengths as close to the targets as possible. (Weigel and Wilcox, 1993:283)

The second level of the MOLS model is a series of models representing the MOS's and grades of a career field.

> The formulation is a multi-time-period pure network representing personnel flows similar to those of the T-Model (but at the MOS and grade level of detail) and constrained by the aggregate flows of the T-Model. (Weigel and Wilcox, 1993:283)

The ULS model is used to forecast enlisted strength and distribution actions at the MOS, grade, and unit level of detail. The constraints for the model come from the MOLS models. The model provides the Army with the enlisted distribution plan. It also serves as the basis for recruitment. "The forecasting process is a heuristic one with sub-optimization at each time period" (Weigel and Wilcox, 1993:283).

The modeling techniques used in the above models are extensive and many of them use a combination of techniques. One of the core techniques used in the Army manpower models is inventory projection. Projection modeling works very well in military applications because the population is easily segregated into different states. "It is frequently necessary to model the force by year of service as well as time to the end of service, for example. Rank and military specialty are other prime candidates for appearance as dimensions" (Weigel and Wilcox, 1993:283). The greatest challenge in this type of model is its size; as the model grows in size, the time it takes to process the model grows exponentially. "Inventory projections fit in with the "what it?" concept for decision support systems very well, as the projection assumptions are input and the projection is the output" (Weigel and Wilcox, 1993:284).

Most manpower models use some type of linear program. Many of the linear programming models use inventory projection as its framework. "Linear programs are conceptually more complex than inventory projections, and have a tendency to be treated as decision-making systems, as the formulation attempts to find what is the best subject to a set of constraints" (Weigel and Wilcox, 1993:284). The biggest advantage of using linear programming over non-linear programming is that linear programming can handle much larger problems. Even though most problems in the real world are non-linear in nature, many of these problems can be handled using linear programming through the use of piece-wise linear approximations. In manpower modeling, the optimal solution represents the best course of action for management to pursue in the area of personnel retention and recruitment.

A network structure is the basis of most linear manpower models. Networks are represented using node and arc structures. The nodes represent states in the model while the arcs represent the rates of flow from and to those states. The capacity that flows into and out of these nodes is bounded. "Unless a node has a supply or demand in it, the amount going in is equal to the amount going out" (Weigel and Wilcox, 1993:284). The arcs direct the flow through the model while attempting to satisfy the objective function. "In military manpower modeling applications, the network structure represents the flow of people and their status at different times" (Weigel and Wilcox, 1993:284). The disadvantage of a network formulation is that it does not support many of the decision constraints required in manpower models. However, there are advantages to its basic structure. Special algorithms and network codes have been developed that increase the

speed and the ability to handle problems larger than general linear programming codes. (Weigel and Wilcox, 1993)

Another popular linear programming technique used in military manpower models is goal programming. "Goal programming is a feature of the objective function in which a number of variables are targeted towards objectives. For example, end strength is frequently a subject of goal programming" (Weigel and Wilcox, 1993:284). Once these end strengths are determined the goal programming model accesses penalties to units not meeting the goals set in the model. The further away a unit is from its goal the more severe the penalty. The goal of this type of model is to get as close to the objective values as possible. "Goal Programming is easily modeled within a network structure, in which inventory flows along several target arcs placed between two nodes. Under the target, the arcs have incentives, but over the target arcs have penalties" (Weigel and Wilcox, 1993:285).

Multi-criterion goal programming is used when there is more than one goal and the goals are in a prioritized hierarchy. This has been very useful in military modeling because many of the problems being modeled have a prioritized set of objective functions. The model finds the best solution for the first objective function and then works its way through the rest of the functions based on priority. Each function may have alternate optimal solutions, in which case, the model chooses the solution that provides the best solution for the next objective function. "This procedure enables one to assure decision makers that trade-offs are not being made between objective functions, as happens when the objective functions combines goals" (Weigel and Wilcox, 1993:285).

Air Force Modeling

The literature on Air Force Modeling techniques is scarce but after interviewing Air Force manpower analysts and reviewing some of their manpower models it is apparent that the Air Force, like the Army, uses a variety of modeling techniques. The military departments have similar modeling objectives which center on maintaining the right number and mix of personnel to accomplish the mission. Both the Air Force and the Army are large hierarchical organizations established to carry out part of the DoD mission. In many instances, the same contractors are used to develop models for both military departments.

Along with the aforementioned similarities, most Army and Air Force models deal with the entire population of their respective departments. This causes some of the small but important aspects of the manpower inventory to get lost in the larger objectives. For instance, a model that focuses on recruiting a certain number people to support the Air Force may not capture the requirements of each career field within the Air Force. Not taking each career field into account could cause overages in some career fields and shortages in others. This type of problem is what initiated the interest in this research effort. While there are models that take into account each career field and even the grade mix in each career field, there are no models to specifically analyze skill level mix within a career field. Also, there are no models available for career field managers to assess the state of their enlisted force. With these types of models available, career field managers will have the ability to assess the state of their skill level inventory as well as support and defend any position they may have on recruitment and retentio n practices and policies.

Summary

The techniques used in developing models for this research effort were derived from articles presented in this literature review and interviews conducted with Army faculty members at AFIT and Air Force manpower analysts at AFPOA/DPY. The literature review provided a great deal of insight into the vast number of modeling techniques available along with the strengths and weaknesses of each technique. The literature search also provided some insight into the types of models used in the military today. Identifying the models that have been developed in the Air Force, and, more importantly, what information those models provide, helped identify the gap in the Air Force's Modeling inventory. The gap identified in the modeling inventory is the small, focused, user- friendly models dealing with specific aspects of individual career fields. This gap was further supported by SAF/AQC's interest in tracking enlisted skill level inventories. These two discoveries were the driving force behind this research effort. This research effort provides a decision support system specifically designed for contracting career field managers. AFPOA/DPY has expressed interest in making these models available to all career field managers to help them manage their career field's skill level inventories.

III. Methodology

Introduction

This chapter discusses the methodology used in developing a DSS for the contracting career field. The DSS is made up of three manpower models: a deterministic model, a stochastic model and an optimization model. The manpower models display current and future manpower inventory levels based on fiscal year, time in service (TIS) and skill level. The chapter begins with a discussion of the personnel involved in the modeling effort followed by a brief description of skill levels. The skill level description includes an explanation of training, time lines, and grade/rank requirements necessary to progress from one skill level to the next. The chapter concludes with a description of how the models were developed including data requirements and assumptions. A major focus of this research is to build accurate, user-friendly models that contracting career field managers can use in manpower planning and decision-making.

Personnel

The contracting career field in the Air Force is made up of both officer and enlisted personnel. This thesis examines the enlisted side of the career field. The interest in modeling the enlisted force, based on TIS and skill level, was identified by contracting career field managers at the Office of the Secretary of the Air Force for Acquisitions (SAF/AQC). These career field managers expressed concern in the recruitment and retention rates of their enlisted force. The managers are also concerned with the increasing numbers of career airmen opting to retire as soon as they are eligible.

Enlisted personnel enter the contracting career field by either direct or pipeline accessions or retraining from another career field. These two distinct options for recruiting personnel create challenging issues for career field managers trying to balance the career field's manpower inventory. It is important for career field managers to have a thorough understanding of how the characteristics of both pipeline and retrainees influence skill level inventories. This knowledge is imperative to achieving and maintaining the right number and skill level mix of personnel.

In the last couple of years the majority of personnel entering the contracting career field have been retrainees. According to the Air Force Personnel Office, last year the contracting career field recruited approximately 180 accessions made up of approximately 120 retrainees and 60 pipeline personnel. The large number of retrainees, whom are more difficult to track, has increased the need for a tool to assist career field manager's access the impact these retrainees have on the future manpower structure of the career field.

The difficulty in tracking retrainees stems from the differences between them and pipeline accessions. Retrainees are further along in their careers, having more rank and longer time in service. They also have more experience in the Air force and upgrade earlier to the next skill level. The primary goal of career field managers is to recruit and retain the right number of personnel to support the mission while assuring they have the right mix of ranks and skill levels to fill all positions. This goal has been challenging because of the aforementioned differences, which makes it difficult to predict future skill level inventories.

Skill Levels

Skill levels are used in the Air Force to identify where a person is with respect to his or her training and experience. These skill levels are attached to the end of the Air Force Specialty Code (AFSC) that identifies the career field an individual belongs too. For example, a contracting person with a 3-skill level is identified by the AFSC number 64P3; 64P identifies the contracting career field while the 3 identifies the skill level.

PIPELINE AND RETAINEE SKILL LEVEL PROGRESSION

Table 1. Ranks

Recruits	1-Skill Level	3-Skill Level	5-Skill Level	7-Skill Level	9-Skill Level
Pipeline	Airmen Basic (AB)	Airmen Basic (AB), Airmen (AMN), and Airmen First Class (A1C)	Airmen First Class (A1C), Senior Airmen (SrA)	Staff Sergeant (SSgt), Technical Sergeant (TSgt), and Master Sergeant (MSgt)	Senior Master Sergeant (SMSgt) and Chief Master Sergeant (CMSgt)
Retrainee	AMN, A1C, SrA, SSgt, TSgt, or MSgt	AMN, A1C, SrA, SSgt, TSgt, or MSgt	SrA, SSgt, TSgt, or MSgt	SSgt, TSgt, or MSgt	SMSgt, CMSgt

Table 2. Time to Upgrade

Recruits	1-Skill Level	3-Skill Level	5-Skill Level	7-Skill Level	9-Skill Level
Pipeline	Complete 6 weeks of Basic Training	6 weeks of Technical Training	Minimum 15 months, average 18 months, maximum 24 months	Between 1 and 2 years after making SSgt; 5 to 12 years TIS with average 9 years TIS	When promoted to the rank of SMSgt
Retrainee	Immediately upon cross training into the career field	6 weeks for Technical Training	Minimum 9 months, average 18 months, maximum 24 months	Most are SSgt and TSgt or will be SSgt in time to begin 7 level training; average 4 years time in career field, not TIS	When promoted to the rank of SMSgt

Table 3. Training and other Requirements

Recruits	1-Skill Level	3-Skill Level	5-Skill Level	7-Skill Level	9-Skill Level
Pipeline and Retrainee	Basic Training or being selected to cross train into career field	Complete Contracting Apprentice technical school at Lackland AFB	Complete 5-skill level Contracting Career Development Course (CDC)	Minimum rank of SSgt	Minimum rank of SMSgt
			Minimum 15 months upgrade training (9 months if retrainee who processed a 5 skill level in prior career field	Minimum 12 months upgrade training	
			Complete all core task training and other duty position requirements identified by supervisor	Completion of the APDP Level II required courses and Contingency Contracting (CON 234)	Satisfy all duty position training requirements
			Meet mandatory requirements listed in specialty description in AFMAN 36-2108 and the Contracting Training Plan.	Meet mandatory requirements listed in specialty description in AFMAN 36-2108 and the Contracting Training Plan.	
				Recommended by supervisor	

<u>NOTE:</u> For a more detailed description of the training and knowledge requirements refer to the Contracting Career Field Education and Training Plan.

The above tables display the different requirements of both pipeline accessions and retrainees. Training requirements are identical but grade, rank and time requirements are significantly different. The largest difference centers on when most retrainees enter the career field. Most retrainees have attained the rank of SSgt or are promoted to SSgt by the time they are eligible to begin 7 level training. This allows retrainees to upgrade from skill level 1 to skill level 7 in about one half the time it would routinely take a pipeline accession. In other words, pipeline accessions upgraded to a 7-level 1 to 2 years after being promoted to the rank of SSgt while retrainees upgraded to a 7-level 1 to 2 years after being awarded a 5-level.

Table 4. Skill Level Upgrade Timeline

Average Time to Upgrade		
Skill Level	Time	
	Pipeline	Retrainee
3	3 months	6 weeks
5	18 months	18 months
7	9 years TIS	3 to 4 years time in career field

Model Development

Career field managers at SAF/ACQ have expressed interest in a tool that would enable them to predict the future state of the enlisted force by skill level. These managers have been noticing troubling trends in the recruitment and retention rates within the contracting enlisted force. The recruiting and retention rates for first term, second term and career airmen have continually decreased over the last decade. These recruiting and retention problems have raised career field manager's interest in personnel modeling tools.

The Markovian process is a modeling technique used extensively in military personnel models because it provides an accurate projection of future manpower inventories. The Markov process is the foundation of this research effort and the foundation of all three models that were developed. The Markov models provide career field managers with a yearly estimate of 3-, 5- and 7-level inventories for a 20-year period. These estimates assist career field managers in making recruiting and retention decisions.

Appendices A and B display two small excerpts of the two Markovian based network flow diagrams developed for this modeling effort. These diagrams give an

example of how personnel flow from one year to the next and one skill level to the next. The full version of each network flow diagram covers 24 years TIS, 3,5, and 7 skill levels, and 20 fiscal years excluding the present year. The node and arc structures present a clear representation to use in building the spreadsheet models. Each node represents a particular state, which is represented by the variable in its center. "A state is defined as a subset of the population under consideration whose members are differentiated from all other members of the population on the basis of one or more characteristics of the individual members of the population. Each member of the population must be a member of one, and only one, state of the system" (Merck and Hall, 1971:5). Each arc represents flow of personnel from one state to the next. Each arc is color coded to signify the type of flow: an accession, a loss rate, movement within the same skill level, or movement to the next skill level.

Variable Designation and Interpretation

The variable structure at the center of each node describes each state in the model. "The utility of the Markovian process depends upon the definition of meaningful subsets of the population, referred to as "states," from and into which all movement occurs with statistical regularity. A state is defined as a subset of the population under consideration whose members are differentiated from all other members of the population on the basis of one or more characteristics of the individual members of the population" (Merck and Hall, 1971:5).

The variable, $P_{i,j,k}$, is used for pipeline accessions. P represents pipeline; i ranges from 0 to 20 representing the fiscal year with a 0 for the current fiscal year and 20 for fiscal year plus 20; j represents the TIS with 0 for new accessions increasing to 24 for

those with 24 years TIS; and *k* represents skill level with a 3,5, or 7 representing either a 3-, 5-, or 7-skill level. For example, a $P_{2,2,3}$ is a 3 level pipeline accession in fiscal year plus 2 with 2 years TIS.

Retrainee variables were done in a similar fashion. The retrainee variable is $R_{i,j,k}$ with the $_{-1}$ subscript added when required. R represents retrainee; *i* is defined identically to pipeline accessions; *j* ranges from 4 to 24 years TIS with 4 representing 4 years TIS or less and 24 representing 24 years TIS; *k* is also defined identically to pipeline accessions; $_{-1}$ represents the years of training in a particular skill level $_{-1}$ for 1 year of training and $_{-2}$ for 2 years of training. The $_{-1}$ is only used when required, to distinguish between two variances of a state. For example, a $R_{11,5,3-2}$ is a retrainee in fiscal year plus 11 with 5 years TIS at the 3-skill level and 2 years of 3 level training.

Data Requirements

Data is an integral part of any modeling effort. Without access to accurate and timely data, models become more of a liability than a benefit. Specious and untimely data leads to erroneous information, which actually leads to inferior decision-making. Developing models with accurate and timely data is critical to the capability of the model itself and to the user's ability to make improved and more informed decisions.

Data requirements for this model include: contracting career field loss rates, contracting SSgt promotion rates, contracting transition rates or training timelines, number of personnel currently in the career field and what state they currently belong too, how many people are required in each skill level, and of the current force what percentage have 1 year training in there current state and what percentage have 2 years of training in their current state. SAF/AQC provided data on the enlisted forces training

requirements and training timelines. AFPC provided data on the contracting career field's enlisted manpower authorizations by skill level. Headquarters United States Air Force, Program Development Division for the Directorate of Manpower Organizations (HQ USAF/XPMP) provided data on the current number of enlisted troops including what skill level they belong to. AFPOA/DPY provided data on the contracting career field's loss and promotion rates.

Models

The initial modeling requirement was to build a conceptual framework illustrating the growth of both pipeline accessions and retrainees from a 3-skill level to a 7-skill level. The resulting network flow diagrams, illustrated in appendices A and B, covers the current fiscal year and 20 additional fiscal years to allow for steady state analysis. Modeling the steady state allows career field managers to visualize the consequences associated with both short- and long-term decisions. The network flow diagram covers both pipeline and retrainees out to 24 years TIS. At 24 years TIS all personnel leave the scope of the model because they either reach high year tenure or are upgraded to the 9-skill level.

The transitions of the Markov process used in developing all three manpower models in the DSS are described using the tree structure below. "In the Markov process, experiments are performed at regular intervals and have the same set of outcomes or states" (Goldstein and others, 1998:368). In the three models developed for this research effort, measurements are taken yearly and the transitions consist of leaving the career field, remaining in the same skill level in the next year or progressing to the next skill level in the next year. The total sum entering a particular state must equal the total sum

leaving that state, this is know as the conservation of flow. The conservation of flow is a method used to maintain accountability. The states are represented by nodes and are linked by the arcs or transitions identified above.

Below is an example of one group, P_{065}, leaving a particular state; the rates provided are notional. This is a group of pipeline accessions with 5 years TIS at a 5-skill level. In this group 10 percent is lost through attrition, 60 percent remain a 5-skill level for another year and 30 percent move to the 7-skill level. This process, depicted in the diagram below, was accomplished for each and every state for both pipeline and retrainees.

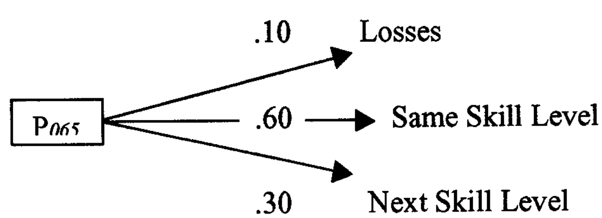


Figure 2. Flow of Personnel from One State

The Markovian approach is the main support for this research effort and provides the framework for the decision support system. The decision support system consists of three models, a deterministic model, a stochastic model, and an optimization model. The Markovian flow diagrams were used as input for developing excel spreadsheets representing all the transitions taking place between the states. The home page of the decision support system allows the user to select from the 3 models. Each model consists of three worksheets, the first worksheet displays the results and changing cells, the back two worksheets separate pipeline accessions from retrainees and maps the inflows and

outflows of each state. Each model uses the Markovian process for its structure and all are user-friendly. The initial worksheet is where career field managers will make changes and analyze the effects of those changes. The models display nearly instantaneous results to any change. The results section displays actual inventory numbers and is color coded to signify when a skill level is under 80 percent manned, between 80 percent and 90 percent manned and over 90 percent manned. This decision support system provides contracting career field managers with a great deal of manpower information, which they can use to make more informed decisions dealing with recruitment and retention.

The deterministic model and the stochastic model are very similar. Both models display the current and future skill level inventories based on certain transition rates. The deterministic model allows career field managers to change and update loss rates, personnel accessions, and SSgt promotion rates as well as analyze the steady-state impact of those changes. The user is able to run several "what-if" scenarios to support recruitment and retention decisions and policy changes. The stochastic model is very similar with the exception of the loss rates. The stochastic model allows career field mangers to access the impact of variable loss rates and to analyze the risk associated with each possible inventory outcome. The stochastic model is set up to run simulations based on a triangular distribution using plus or minus 15 percent of FY2000 loss rates. (AFPOA/DPY stated that the plus or minus 15 percent of FY2000 loss rates covers 99% of loss rates encountered over the last 20 years including the personnel draw-down.) The FY2000 loss rates were generated by AFPOA/DPY. The simulations allow the user to determine how sensitive skill level inventories are to historical loss rates.

The optimization model is the last of the three manpower models that make up the decision support system. The optimization model is used to generate recruiting strategies and to display the results of implementing those strategies. The model is set up to minimize the maximum deviation between the actual skill level inventory numbers and their respective target values. This model is very user friendly and allows career field managers to make changes based on their experience and knowledge, to generate more meaningful solutions. Changes are allowed to current inventory, loss rates, promotion rates, manpower authorizations, manpower constraints, and skill level weighting.

The weights in the model allow the user to prioritize the under- or over-achievement of any skill level based on career field priorities. For example, applying a weight to the 5-level underachievement deviational variable forces the model to prioritize the underachievement of 5-levels before addressing the other skill level objectives. The emphasis given to the skill level depends on the magnitude of the weight and the weights applied to the other variables.

The ability to set constraints in the model is another valuable feature of the optimization model. This feature allows the user to add real world constraints into the model increasing the precision and utility of the solutions. For example, contracting career field managers insist that the total manpower inventory must remain above 80% in order to successfully carry out the mission. To ensure this objective is met a constraint is added forcing the model to only select solutions that maintain the 80% manning requirement.

Another example of constraints is the upper bounds placed on the distribution of retrainees. This set of constraints forces the model to bring in a realistic distribution of

retrainees. Without the constraints the model may decide to bring in 120 retrainees with the same TIS years in the same fiscal year. It is unlikely, if not impossible, to recruit 120 retrainees with the same TIS in the same fiscal year. This constraint allows career field manager's to manipulate the distribution of retrainees and to analyze the difference between recruiting retrainees early in their career as opposed to late in their career. The optimization model is a very useful and versatile tool, providing the user with a wealth of manpower knowledge to use in making recruiting and retention decisions. The optimization model is the most powerful and informative tool in the decision support system.

The goal programming mathematical model is ...

Min: Q

Subject to:

(1) $Wk^*[(d\text{-}k, d\text{+}k)/Tk] \leq Q$
(2) $\Sigma(Pij3 + Rij3) + d\text{-}3 - d\text{+}3 = T3$
(3) $\Sigma(Pij5 + Rij5) + d\text{-}5 - d\text{+}5 = T5$
(4) $\Sigma(Pij7 + Rij7) + d\text{-}7 - d\text{+}7 = T7$
(5) $tj \geq 1184$, j goes from 1 to 24
(6) $P0j3 \leq 60$, j going from 1 to 24
(7) $Rij3 \leq 120$, i going from 4 to 17 and j going from 1 to 24
(8) $Pijk$, $Rijk$, $d\text{+}k$, $d\text{-}k \geq 0$

$d\text{-}k$ = amount by which skill level k inventory goals are underachieved
$d\text{+}k$ = amount by which skill level k inventory goals are exceeded

ti stands for total skill level inventory with i going from 0 to 24 for current year through fiscal year+20

Wk stands for the weight with k being a 3, 5, or 7 representing skill level.

Tk stands for Target inventory with k being a 3, 5, or 7 signifying skill level.

The objective function and constraints displayed above are used in the manpower optimization model. The objective function minimizes the maximum deviations between the actual inventory numbers and the target inventory numbers. In essence, the model minimizes the maximum deviations, either over or under, from the skill level inventory

goals based on the weights assigned to those goals. The weights are based on skill levels importance to the career field at that particular time. The constraints are used to establish target goals and to place caps on the maximum number of pipeline and retrainees that can be recruited in any one-year period. The constraints are based on past recruitment numbers and the availability of training slots.

Assumptions

Assumptions were made throughout model development to address certain personnel issues and to formulate tractable models. Contracting career field managers and Air Force manpower analysts at AFPOA/DPY deemed all assumptions acceptable and necessary.

The first three assumptions are required when using the Markov process. Again, these assumptions include:

1. Each individual is governed by the Markov process and only the last state occupied determines the individuals next state.
2. The same Markov process applies to all individuals.
3. All individuals behave independently.

Other general assumptions include:

1. Transition rates remain constant.
2. The categories or states in the model remain constant.
3. Training timelines remain constant.
4. Skill level timelines remain constant.

The remaining assumptions deal mainly with the personnel involved in this modeling effort.

In order to establish a model based on fiscal year an assumption is required which allows all movement within the model to take place at the same time. The assumption representing this principle is that all pipeline and retrainees in a particular state are considered to have completed that state by the end of that fiscal year. Therefore, movement occurs at the end of each fiscal year. This assumption is made to accommodate the yearly scale used in all three models. As groups progress through the model there are some individuals with more time than others in a particular state, but when considering all the states together the differences become negligible. The minimum time required for retrainees to upgrade to the 5-skill level presented a modeling concern. In reality, retrainees can potentially upgrade to the 5-skill level 9 months after being awarded a 3-skill level. This creates an additional requirement in the model because the vast majority of retrainees upgrade in the next state between the 12^{th} and 24^{th} month. To alleviate this problem it is assumed that all retrainees upgrade to 5-skill level between the 12^{th} and 24^{th} month after being awarded a 3-skill level. This assumption does not significantly affect the accuracy of the model because of the small number of people that fall into the 9 to 12 month category.

All personnel enter the models as a 3-skill level. The assumption is based on the fact that everyone in the career field upgrades to a 3-skill level immediately following completion of the contracting residents course and the length of time spent, as a 1-skill level is 3 months or less. Any individuals in the current inventory holding a 1-skill level were placed in a 3-skill level category. This assumption does not have a significant affect on the accuracy of the model.

The next assumption deals with the length of time retrainees have been in the career field. This is important because currently there is no straightforward method of determining how long retrainees have been in the contracting career field. In order to accurately model the current retrainees in the career field the models must determine the length of time each retrainee has spent in their current state. Since it takes a retrainee two years to progress from one skill level to the next, one-half of the current retrainee inventory will have one year or less in their current state and the other half has one to two years. This assumption is for all current retrainees except those with 4 years TIS. At 4 years TIS no rate is required because it is assumed to be the earliest a retrainee enters the career field. This additional assumption places 100% of the retrainees with 4 years TIS in the same state. Some retrainees enter the career field prior to 4 year TIS, but this number is insignificant.

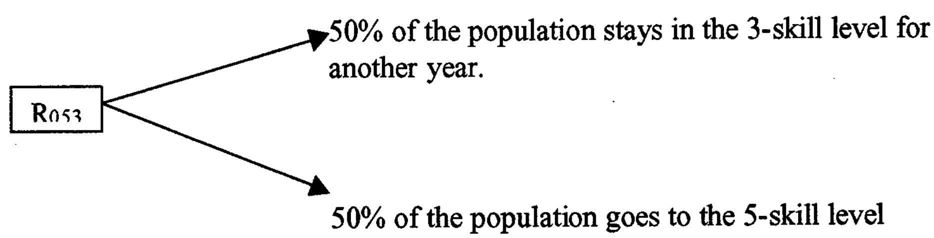


Figure 3. Flow of Retrainees from One Initial State

Figure 3 represents the 50% assumption. The figure demonstrates the flow of retrainees out of a current state. One-half of the current retrainee population remains in their current skill level for an additional year, while the other half is upgraded immediately following this initial state. These assumptions were discussed with Air Force analysts

and considered reasonable. The analysts concur that the assumption does not have a significant affect on the accuracy of the model.

Loss rates used for pipeline accessions apply to retrainees as well. This assumption is required because loss rates are not segregated for pipeline accessions and retrainees. They are tied to the career field as a whole. This, of course, is not completely accurate because of the mandatory TIS commitments incurred by retrainees, but career field managers and Air Force analysts claim that the difference is insignificant.

Promotion to the rank of SSgt is required to begin 7-level training. The SSgt requirement is the primary reason for separating pipeline accessions and retrainees. Most retrainees enter the career field with the rank of SSgt or higher or are promoted to the rank of SSgt prior to 7-level eligibility. For this reason, the vast majority of retrainees are not affected by the SSgt requirement. Therefore, the assumption is that all retrainees are promoted to the rank of SSgt prior to 7-level eligibility. The small number of retrainees not meeting the SSgt requirement is insignificant and therefore does not affect the accuracy of the model. If the promotion time to the rank of SSgt continues to shorten this assumption will become superfluous.

The pipeline portion of the model includes the SSgt requirement to determine when an individual begins 7-level upgrade training. The model accounts for the requirement by utilizing Air Force promotion rates. The promotion rates are tied to TIS for all pipeline accessions. The rates determine what percentage of pipeline personnel begin 7-level training at 6 years TIS, 7 years TIS, and so on, to 12 Years TIS. For example, a pipeline accession that is promoted to SSgt at 4 years TIS, the earliest date

possible, would complete 7 level training at or prior to 6 years TIS. The assumptions made to accommodate this situation are:

1. Pipeline personnel are promoted to SSgt at the same rates as in the past
2. The rates for contracting personnel are the same as the Air Force rates
3. Promotion rates remain constant.

Career field managers and Air Force analysts feel that these assumptions are reasonable.

The final assumption in this research effort deals with personnel leaving the model at 24 years TIS. This assumption is based on high year tenure set by Air Force policy. The policy forces individuals to leave the Air Force after 24 years TIS unless promoted to the rank of SMSgt. Even those promoted to the rank of SMSgt leave the model because they lie outside the scope of the model.

IV. Results and Analysis

Introduction

This chapter displays the results of the DSS developed for this thesis. Results were taken directly from the manpower models using different experimental sets of parameters to demonstrate the capabilities of the models. Each solution set generated is documented below along with the parameters used to generate those solutions and a synopsis of the results. It is important to point out that all solutions are based on the assumptions listed in chapter 3 and the parameters used during each trial. Career field managers possess the knowledge and experience to select appropriate parameters to generate practical solutions to improve recruitment and retention decisions. SAF/AQC, AFPC, HQ USAF/XPMP and AFPOA/DPY provided all the data used in developing these three manpower models.

Deterministic Model

The Deterministic model is used to display the steady state inventory based on forecasted recruiting projections. The model is also used to determine the effects of recruiting changes made to the mix of pipeline and retrainee accessions. The tables below display the settings used for each set of inventory results listed in Figures 4 through 8.

Table 5. Accessions Settings for Deterministic Model

Model Settings					
Model Settings by Figure	Figure 4.	Figure 5.	Figure 6.	Figure 7.	Figure 8.
Accessions Per Year	60 Pipeline 120 Retrainees	85 Pipeline 95 Retrainees	120 Pipeline 60 Retrainees	180 Pipeline 0 Retrainees	0 Pipeline 180 Retrainees
Distribution of Retrainees by TIS					
TIS	Number of Retrainees				
4 years	20	15	10	0	28
5 years	4	3	2	0	4
6 years	4	3	2	0	5
7 years	5	4	3	0	6
8 years	10	8	4	0	12
9 years	10	8	4	0	12
10 years	12	10	7	0	15
11 years	12	10	7	0	15
12 years	12	10	7	0	15
13 years	12	10	7	0	15
14 years	10	8	4	0	12
15 years	7	5	2	0	8
16 years	2	1	1	0	3
17 years	0	0	0	0	0

Table 5 displays the settings used for each trial of the deterministic model. The table illustrates the number of pipeline and retrainees recruited yearly in each trial as well as the distribution of retrainees used for that trial. Settings were changed in each trial to demonstrate the capabilities of the model. The numbers and distribution in Figure 4 were used to illustrate the results of continuing current recruiting patterns. Figure 5 was used to illustrate the effects of recruiting a relatively even mix of pipeline and retrainees. Figure 6 was chosen to illustrate the effects of recruiting the opposite mix of pipeline accessions and retrainees. Figures 7 and 8 were selected to illustrate the effects of recruiting from only one group of personnel.

Table 6. SSgt Promotion Rates

SSgt Promotion Rates by TIS	
TIS	**Percentage Promoted**
4 years	13%
5 years	23%
6 years	27%
7 years	22%
8 years	12%
9 years	2%
10 years	1%
Total	**100%**

Table 6 displays the SSgt promotion rates used for all three manpower models. The promotion rates are based on fiscal year 2000 promotion rates. High year tenure for those that are not promoted to SSgt is 10 years. These losses are figured into the 10-year TIS loss rate.

Table 7. Contracting Loss Rates

Contracting Loss Rates by TIS	
TIS	**Loss Rates**
1 year	0.118
2 years	0.160
3 years	0.138
4 years	0.465
5 years	0.024
6 years	0.129
7 years	0.135
8 years	0.222
9 years	0.101
10 years	0.085
11 years	0.079
12 years	0.067
13 years	0.025
14 years	0.014
15 years	0.014
16 years	0.013
17 years	0.026
18 Years	0.009
19 years	0
20 years	0.403
21 years	0.307
22 years	0.455
23 years	0.375
24 years	0.625

Table 7 displays the loss rates used for all three manpower models. The loss rates are based on fiscal year 2000 loss rates. Loss rates have been relatively constant over the last three years. Critically high loss rates to emphasize are the ones that occur at the conclusion of the first and second enlistments, year four and eight.

Table 8. Manpower authorizations and Critical Range

Contracting Manpower Authorizations and Critical Range			
Skill Level	**Manpower Authorization**	**80% of Authorizations**	**90% of Authorizations**
3	123	98.4	111
5	848	678	763
7	509	407	458

(The critical range was established by contracting career field managers at SAF/AQC. Below 80% is undermanned, 80% to 90% is marginally manned, and above 90% is adequately manned.)

Table 8 shows the manpower authorizations for the contracting career field based on skill level. The last two columns represent manpower boundaries identified by contracting career field managers at SAF/AQC as critical points in skill level inventories. The boundaries establish 3 critical ranges, below 80% manned, between 80% and 90% manned and above 90% manned. When a skill level is below 80% the mission is in jeopardy, between 80% and 90% the mission is being accomplished but the inventory is monitored more closely to prevent it from dropping below 80%. Above 90% manned the mission is being accomplished and there is no imminent threat of being undermanned. All three models permit the analyst to alter these decision criteria after receiving guidance from the decision maker.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3																					
5																					
7																					
Totals	1266	1290				1330	1317	1305	1303	1298	1291	1302	1310	1327							

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 4. 1st Trial of Deterministic Model

Figure 4 displays skill level inventories based on the continuation of current recruiting patterns, which is to recruit 60 pipeline accessions and 120 retrainees. The distribution of retrainee accessions is similar to the retrainee distributions over the last three fiscal years. If the career field managers continue to recruit in this fashion, 3-level inventories reach steady state at 336 in fiscal year plus 2; 5-level inventories decrease and reach steady state at 365 in fiscal year plus 12 and 7-level inventories remain above 90% increasing to 633 in fiscal year plus 20. Total inventories fluctuate before increasing above 90% in fiscal years plus 14 through plus 20. Although 5-level inventories are severely undermanned the overages in 3- and 7-level inventories are large enough to overcome those shortages and to maintain total inventories above 90%.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3																					
5																					
7																					
Totals	1266	1290				1318	1296	1276	1267	1256	1244	1251	1258	1272	1283	1288	1289	1287	1282	1283	1282

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 5. 2nd Trial of Deterministic Model

Figure 5 displays the skill level inventories based on recruiting 85 pipeline personnel and 95 retrainees as opposed to 60 pipeline personnel and 120 retrainees. The

percentages used for the distribution of retrainee accessions are similar to the percentages currently used but the number of retrainees in each TIS are smaller to account for the smaller number of retrainee recruits. If career field managers decide to recruit in this fashion, 3-level inventories reach steady state at 337 in fiscal year plus 2; 5-level inventories decline to 358 in fiscal year plus 6 before increasing and reaching steady state at 389 in fiscal year plus 12. 7-level inventories fluctuate but remain above 90% through fiscal year plus 20. Total inventory rises above 90% in fiscal year plus 2 before decreasing to between 80% and 90% in fiscal years plus 5 through plus 20. Comparing these results to the base case in Figure 4 demonstrates the effects of recruiting more pipeline accessions and fewer retrainees. An increase in pipeline accessions increases 5-level inventories and decreased 7-level inventories because pipeline accessions remain in the 5-skill level for a longer period of time. Total inventories also decrease as pipeline accessions increase because pipeline accessions face higher loss rates in the early years, especially at 4 years TIS. Refer to Table 7 for a closer look at the loss rates.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
5	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
7	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	436	413	413	412	423	433	438	440	440	436	439	440
Totals	1266	1290	[redacted]	[redacted]	[redacted]	1298	1263	1231	1210	1188	[redacted]	[redacted]	[redacted]	[redacted]	1193	1198	1200	1200	1196	1199	1200

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 6. 3rd Trial of Deterministic Model

Figure 6 displays the skill level inventories based on recruiting 120 pipeline personnel and 60 retrainees as opposed to 60 pipeline personnel and 120 retrainees, which are the current recruiting numbers. The percentages used for the distribution of

retrainee accessions are similar to the percentages currently used but the number of retrainees in each TIS are smaller to account for the smaller number of retrainee recruits. If career field managers decide to recruit in this fashion, 3-level inventories reach steady state at 337 in fiscal year plus 2; 5-level inventories decline to 356 in fiscal year plus 3 then increase and reach steady state at 423 in fiscal year plus 12 and 7-level inventories decline from 90% in fiscal years plus 1 through plus 8 to between 80% and 90% in fiscal years plus 9 through plus 20. Total inventories drops below 80% in fiscal years plus 10 through plus 13 before rising to between 80% and 90% in fiscal years plus 14 through plus 20. Comparing these results to the base case further emphasizes that as the number of pipeline recruits increases and the number of retrainees decreased, the 5-skill level inventories increase and the 7-level inventories decrease. Again, this is due to pipeline accessions remaining in the 5-skill level for a longer period of time.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Totals	1266	1290	[illegible]	[illegible]	1325	1265	1209	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 7. 4th Trial of Deterministic Model

Figure 7 displays the skill level inventories based on recruiting 180 pipeline personnel and 0 retrainees as opposed to 60 pipeline personnel and 120 retrainees, which are the current recruitment numbers. This type of recruiting approach is helpful in demonstrating the changes that occur from recruiting only pipeline personnel. If career field managers decide to recruit in this fashion, 3-level inventories reach steady state at

339 in fiscal year plus 2; 5-level inventories decline to 352 in fiscal year plus 3 before increasing and reaching steady state at 481 in fiscal year plus 12 and 7-level inventories drop below 80% in fiscal year plus 7 and continue to fall ending at 239 in fiscal year plus 20. Total inventories also fall below 80% in fiscal year plus 7 and continue falling to 1059 in fiscal year plus 20. These results further emphasis the effects of recruiting pipeline accessions as opposed to retrainees.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Totals	1266	1260	1274	1280	1248	1234	1220	1209	1209	1206	1201	1212	1218	1234	1244	1246	1244	1240	1230	1226	1219

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 8. 5th Trial of Deterministic Model

Figure 8 displays the skill level inventories based on recruiting 0 pipeline personnel and 180 retrainees as opposed to 60 pipeline personnel and 120 retrainees, which are the current recruiting numbers. This type of recruiting approach is helpful in demonstrating the changes that occur from recruiting only retrainees. If career field managers decide to recruit in this fashion, 3-level inventories reach steady state at 277 in fiscal year plus 2; 5-level inventories decline before reaching steady state at 255 in fiscal year plus 12 and 7-level inventories fluctuate but stay above 90% through fiscal year plus 20. Total inventories also fluctuate but stay within 80% and 90% of throughout the model. These results illustrate the negative impact retrainees have on 5-level inventories and the positive impact they have on 7-level inventories. Again, this is accredited to the short amount of time retrainees spend in the 5-skill level.

Cross analysis of the Deterministic Model

When examining the trials of the deterministic model together two trends become apparent. First, the closer the recruiting strategy gets to an even mix of pipeline and retrainees, as in Figure 5, the better the overall solution. Some of the other trials provided better solutions for individual skill levels but the solution in Figure 5 is the best all around solution. This strategy allows 7-level inventories to remain above 100% while stabilizing the losses sustained in the 5-level inventories at 389. The second trend deals with the effect pipeline and retrainees have on skill level inventories. As the number of pipeline accessions increase and the number of retrainees decrease the 5-level inventories increase while the 7-level inventories decrease. The opposite is also true, as the number of retrainees increase and the number of pipeline accessions decrease the 7-level inventories increase and the 5-level inventories decrease. The reason these changes occur is because pipeline accessions remain in the 5-skill level for a longer period of time. The reason pipeline accessions remain in the 5-skill level longer is because they must be promoted to SSgt in order to begin 7-level training whereas most retrainees are already SSgt by the time they enter the contracting career field. These trends demonstrate the significant capabilities of this model. This type of information can significantly improve a career field manager's ability to balance skill level inventories.

Stochastic Model

The stochastic model is the same as the deterministic model with the exception of loss rates. The stochastic model allows the career field manager to run simulations based on variable loss rates and to analyze the effects that the variability has on skill level

inventories. The stochastic model also acts as a risk assessment tool by identifying the probabilities associated with each inventory outcome. The simulations are based on a triangular distribution using current loss rates plus 15 percent as the upper bound and minus 15 percent as the lower bound. The triangular distribution is used in situations where you know the minimum, maximum, and most likely values. (Crystal Ball 2000, 2001) Air Force analysts at AFPOA/DPY suggested the distribution type and recommended plus or minus 15 percent. The Air Force analysts stated that the upper and lower bounds account for all loss rates experienced in the career field over the last few decades including the personnel draw down of the early 1990's.

The stochastic model was developed using Crystal Ball. The stochastic model's spreadsheets closely resemble the deterministic model's spreadsheets with the exception of an additional column incorporating the parameters and triangular distribution to run the simulations. Each inventory cell in the model, with the exception of the current inventory cells, is a forecast cell in the simulation because the skill level inventories are the cells of interest. The simulation is set up to run 1000 replications and to generate reports on each inventory cell for each time period. The reports provide descriptive statistics on how these different loss rates affect a particular inventory at a particular point in time. An example of the simulation reports, for each skill level, is presented in appendix C.

The simulation's output consists of descriptive statistics on the inventory levels along with frequency charts displaying the results of the 1000 replications. This information allows the career field manager to evaluate the risk associated with pursuing ultimate strategies in recruiting and retention. The graphic capability enables the career

field managers to determine the probabilities associated with exceeding or falling below the criterion established for undermanned, marginally manned and adequately manned thresholds. A frequency chart illustrating the risk assessment capability is presented in appendix D.

The simulations accomplished in the stochastic model indicate the predominately insignificant effects variable loss rates have on current skill level inventories. The simulation reports illustrate an increase in variability as the skill level increases and as the forecasts extend to the out years. These changes reflect the increasing number of variables involved in upgrading from one skill level to the next and the increasing level of difficulty involved in forecasting further out into the future.

The reports on 3-level inventories indicate that variable loss rates have little to no effect. According to the reports, the 3-skill level inventories have almost no variability. The largest range is from 335 to 338 with a mean of 337, which translates into plus or minus one individual. This range occurs in fiscal year plus 2 and remains constant following the steady state inventory through fiscal year plus 20. The reason there is very little variability in the 3-level inventory is because everyone automatically enters the model as a 3-skill level, as far as the model is concerned there are no time or training requirements to accomplish prior to being awarded a 3-skill level. In reality, an individual must complete an in-residence contracting apprentice course before being awarded a 3-skill level. The model assumes everyone successfully completed the course and was awarded a 3-skill level on time.

The reports on the 5-skill level indicate that variable loss rates have some effect on 5-level inventories. The range in fiscal year plus 1 is from 407 to 413 with a range of

6 and a mean of 410. The range in fiscal year plus 10 is from 361 to 385 with a range of 24 and a mean of 371. The range in fiscal year plus 20 is from 361 to 385 with a range of 25 and a mean of 372. These three points illustrate the pattern that is evident throughout the 20-year period. The range starts out small and increases to 20 in fiscal year plus 3 before beginning a small but steady climb to 25 in fiscal year plus 20. As the model closes in on steady state, the variance stabilizes. The variability in the 5-level inventories negligibly affects the results generated. The variability does not cause any of the inventories to fall below or increase above the established decision threshold values.

The reason variability exists in the 5-level inventories is because there is variability in the process. The variability in the process comes from the time it takes and the training required in upgrading from a 3-skill level to a 5-skill level. Individuals seeking a 5-skill level must complete a contracting career development course (CDC) by correspondence as well as meet other training and time requirements identified in the contracting career field's training plan.

The reports on the 7-skill level confirm that variable loss rates have more of an affect on 7-level inventories than any other skill level. The range in fiscal year plus 1 is 2 with a mean of 596. In fiscal year plus 10 the range grows from 590 to 620 with a mean of 604. The range is still growing in fiscal year plus 20, going from 631 to 679 with a mean of 651. While there is variability in the 7-skill level inventory it does not significantly impact the results generated in this research effort. The reason there is more variability in 7-level inventories than in the 3- and 5-level inventories is because there is more variability in the time it takes and the training required in upgrading from a 5-skill level to a 7-skill level. Individuals upgrading to a 7-skill level must be a SSgt promotee

and must meet certain time and training requirements listed in the contracting career field's training plan.

Optimization model

The optimization model is used to generate feasible recruiting strategies for the contracting career field, taking into account constraints on recruitment and minimum manning levels. The model displays the recruitment strategy along with the inventory projections based on that strategy. The model allows the career field managers to identify and emphasize important aspects in their recruitment and retention strategy. These weights allow career field managers the flexibility to generate feasible schedules based on current skill level priorities.

The tables and figures below represent the settings used for the optimization model and results generated by the optimization model. The settings for the optimization model are very similar to the deterministic model. Loss rates in Table 7, SSgt promotion rates in Table 6 and manpower authorizations and boundaries in Table 8 still apply. The difference with the optimization model is that it selects the number and distribution of retrainees along with the number of pipeline accessions. The three additional tables below list the accessions numbers, the upper bounds placed on the distribution of retrainees and the weights used in each trial of the optimization model.

Table 9. Distributions

Model Settings for the Optimization Model			
Accession per year used for all optimization model results		60 pipeline 120 retrainees	
Upper Bounds applied to the Distribution of Retrainees by TIS			
TIS	Upper Bounds for each set of results based on a percentage of total retrainees		
	Figures 9 and 10	Figures 11-18	Figures 19-26
4 years	100%	33%	30%
5 years	100%	7%	30%
6 years	100%	7%	20%
7 years	100%	8%	20%
8 years	100%	17%	20%
9 years	100%	17%	10%
10 years	100%	20%	10%
11 years	100%	20%	10%
12 years	100%	20%	10%
13 years	100%	20%	2%
14 years	100%	17%	2%
15 years	100%	12%	1%
16 years	100%	3%	0%
17 years	100%	0%	0%

Table 9 displays the total accessions allowed for both pipeline and retrainees in any one fiscal year. These numbers represent upper bounds on recruitment; they are based on recent recruiting numbers in the contracting career field. These recruiting numbers are constrained by funding and training availability. The table also displays the upper bounds placed on the distribution of retrainees based on TIS. These upper bounds are necessary in order to generate realistic solutions. Without placing upper bounds on the retrainee distribution the model may generate a solution that includes recruiting 120 retrainees with the same TIS in the same fiscal year. Figure 10 illustrates the problems that occur when no upper bounds are placed on the retrainee distribution. The results in Figures 11 through 18 are based on the upper bound percentages listed in the third column of Table 9. These upper bounds represent recent retrainee recruiting percentages. The recruiting percentages were doubled to provide the optimization model with enough

flexibility to locate a feasible schedule. The third set of upper bound percentages, in column four of Table 9, is based on the contracting career field manager's preferred method of recruiting retrainees. Contracting career field managers have stated that they prefer recruiting retrainees earlier in their careers to utilize them for a longer period of time. In their opinion, the contracting career field gets more return on its investment when they recruit retrainees with fewer years TIS.

Table 10. Skill Level Weights 1

Weights Under and Over Targets for Each Optimization Trial										
Skill level	Figures 9 and 10		Figures 11 and 12		Figures 13 and 14		Figures 15 and 16		Figure 17 and 18	
	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over
3	1	1	1	1	1	1	1	2	1	1
5	1	1	1	1	3	1	5	1	2	1
7	1	1	1	1	1	1	1	1	1	4

Table 11. Skill Level Weights 2

Weights Under and Over Targets for Each Optimization Trial						
Skill level	Figures 19 and 20		Figures 21 and 22		Figures 23 and 24	
	Under	Over	Under	Over	Under	Over
3	1	1	1	1	1	3
5	1	1	4	1	5	1
7	1	1	1	1	1	2

Tables 10 and 11 display the weights used in each trial of the optimization model. These weights are applied to different skill levels and in different patterns to demonstrate the capability of the optimization model. Weights can be applied to a particular skill level and more specifically to the underachievement or overachievement of that skill level. For example, a weight applied to the underachievement of the 5-skill level forces the model to place more emphasis on minimizing the underachievement of the 5-skill level inventory. The degree to which it minimizes the underachievement of the 5-skill

level inventory depends on the magnitude of the weight chosen in comparison to the weights applied to the other skill levels.

An additional constraint used in this model is the lower bound applied to the total inventory. Career field managers stated that if the total manpower inventory dropped below 80% the mission would suffer. To prevent that from happening the constraint on total inventory forces the model to locate schedules that provide a total inventory of at least 1184, 80% of the career field's current manpower authorizations.

The optimization model is flexible enough to allow career field managers to add additional constraints that they feel are appropriate. Career field managers have the experience and knowledge to apply meaningful constraints that will enhance the models ability to identify feasible schedules. For example, even though the manpower authorization for the 3-skill level is 123, the career field normally maintains 300 or more in inventory. If career field managers believe this is a requirement, they could simply add an additional constraint that would force the 3 skill level inventory to remain above 300.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[redacted]																				
5	[redacted]																				
7	[redacted]																				
Total	1266	1239	1241	1250	1214	1203	1189	1185	1189	1185	1185	1185	1185	1185	1185	1185	1185	1185	1194	1185	1185

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 9. 1st Trial of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
Pipeline	1 year	6	0	10	1	9	2	8	3	8	4	6	4	5	0	3	0	3	1	2	60
Retrainee	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11 years	0	36	23	27	56	54	47	64	119	21	0	0	0	0	0	0	0	0	0	61
	12 years	34	84	97	93	64	66	73	56	1	99	120	101	0	0	0	0	0	0	0	0
	13 years	67	0	0	0	0	0	0	0	0	0	0	19	120	0	0	0	0	0	0	0
	14 years	19	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	120	0	0	0
	15 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	120	0	0
	16 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	120	0
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	61

Figure 10. Recruiting Strategy for 1st Trial

Figures 9 and 10 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 9 and 10 display the results of placing 100% upper bounds on the distribution of retrainees and using a unit-weighting scheme for all skill level inventories. If contracting career field managers decide to implement the recruiting strategy suggested in Figure 10, 3-level inventories reach steady state at 241 in fiscal year plus 2, 5-level inventories decline to 224 in fiscal years plus 11 and plus 12 before increasing to 238 in fiscal year plus 20 and 7-level inventories fluctuate but remain above 90% through fiscal year plus 20. Total inventories decrease but remain stable between 80% and 90% in fiscal years plus 9 through plus 20. The major concern with this strategy is that 5 level inventories, which are already below 80%, decreases to below 30%. This may be a viable strategy if career field managers are willing to accept more 7-levels in place of fewer 5-levels

Figure 10 displays the recruiting strategy that achieves the inventory results displayed in Figure 9. The suggested pipeline recruiting strategy calls for less than 10, and, in most cases, less than 5 pipeline accessions each fiscal year. This is significantly different than recent recruiting numbers. This strategy is considered unrealistic due to the distribution of retrainees. Allowing the model to recruit large numbers of retrainees with the same TIS, in the same fiscal year, leads to unrealistic solutions. For example, the optimal schedule recruits 120 retrainees with 12 years TIS in fiscal year plus 12. It is highly unlikely, if not impossible, to recruit 120 retrainees with the same number of TIS years, in the same fiscal year.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	1266	1250	1248	1259	1220	1206	1189	1185	1188	1188	1185	1190	1185	1186	1185	1185	1185	1185	1185	1185	1185

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 11: 2nd Trial of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
Pipeline	1 year	18	0	15	3	14	3	15	7	11	8	10	9	9	7	8	7	8	7	3	37
Retrainee	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	8
	6 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
	7 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8 years	0	0	0	0	0	4	15	4	7	0	4	0	0	0	0	0	0	0	13	20
	9 years	14	4	20	20	5	20	20	20	20	20	20	20	4	1	0	0	0	0	0	20
	10 years	24	24	24	24	24	24	24	24	24	24	24	24	24	24	13	10	10	1	0	0
	11 years	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	12 years	24	24	24	24	24	24	24	24	21	24	24	24	24	24	24	24	24	24	24	0
	13 years	24	24	24	24	24	24	13	24	24	15	24	24	24	24	24	24	24	24	24	0
	14 years	10	20	4	4	19	0	0	0	0	13	0	4	20	20	20	20	20	20	20	0
	15 years	0	0	0	0	0	0	0	0	0	0	0	0	0	3	14	14	14	14	14	14
	16 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	0	0
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	96

Figure 12. Recruiting Strategy for 2nd Trial

Figures 11 and 12 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 11 and 12 display the results of placing the upper bounds listed in column 3 of Table 9 on the distribution of retrainees and applying a unit-weighting scheme to all skill level inventories. If contracting career managers decide to implement the recruiting strategy suggested in Figure 12, 3-level inventories reach steady state at 248 in fiscal year plus 2, 5-level inventories decline to 232 in fiscal year plus 10 before increasing and reaching steady state at 241 in fiscal year plus 18 and 7-level inventories increase and fluctuate but remain above 90% through fiscal year plus 20. Total inventories decrease but remain between 80% and 90% through fiscal year plus 20. The major concern with this strategy is the same as in Figure 9, the 5 level inventories, which are already below 80%, drop below 30%. Again, this may be a viable strategy if career field managers are willing to accept more 7-levels in place of fewer 5-levels.

Figure 12 displays the recruiting strategy that achieves the inventory results displayed in Figure 11. The strategy is a result of optimizing inventory levels while applying upper bounds to recruiting numbers, upper bounds to the retrainee distribution, and lower bounds to total inventories. Figure 12 employs a more realistic recruiting strategy than Figure 10. The strategy calls for less than 20, and, in most cases, less than 10 pipeline accessions each fiscal year, this is much lower than recent recruiting numbers. This retrainee strategy spans only a small section of the overall spectrum of entry points afforded retrainees, concentrating between 9 and 14 years TIS. This strategy is slightly different than recent recruiting patterns.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	1266	1289	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1185

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 13. 3rd Trail of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY+ 20
Pipeline	1 year	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	41	0	0
Retrainee	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	8	8	8	8	8	8	8	4	4	0	0	0	0	0	8	8	0	8	0	0
	6 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9 years	20	20	20	20	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0	0
	10 years	0	24	24	24	24	24	24	24	24	0	0	9	9	9	1	1	10	1	0	0
	11 years	1	24	0	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	21
	12 years	24	24	5	0	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	0
	13 years	24	16	24	5	19	19	19	24	24	24	24	24	24	24	24	24	24	24	24	0
	14 years	20	0	20	20	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20	0
	15 years	14	0	14	14	0	0	0	0	0	7	7	14	14	14	14	14	14	14	14	0
	16 years	4	4	4	4	0	0	0	0	0	0	0	4	4	4	4	4	4	4	0	0
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	117	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	107	21

Figure 14. Recruiting Strategy for 3rd Trial

Figures 13 and 14 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 13 and 14 illustrate the results of placing the upper bounds listed in column 3 of Table 9 on the distribution of retrainees and applying a weight of 3 to the underachievement deviational variable associated with 5-skill level inventories. A unit weight is applied to the remaining deviational variables. The objective of this weighting scheme is to force the model to prioritize the underachievement of 5-level inventories in order to bring them closer to their target value of 848. If contracting career field managers decide to implement the recruiting strategy suggested in Figure 14, 3-level

inventories increase and remain stable until fiscal year plus 18 where they begin dropping to 123 in fiscal year plus 20. 5-level inventories drop in fiscal year plus 1 but level off immediately and remain stable from fiscal years plus 2 through plus 20 and 7-level inventories increase and remain above 90% through fiscal year plus 20. Total inventories increase above 90% in fiscal years plus 2 through plus 19 before dropping to between 80% and 90% in fiscal year plus 20.

Figure 14 displays the recruiting strategy that achieves the inventory results displayed in Figure 13. The strategy is a result of optimizing inventory levels while applying upper bounds to recruiting numbers, upper bounds to the retrainee distribution, and lower bounds to total inventories. The strategy calls for 60 pipeline accessions each year except the last 3 years which closely follows the current strategy. This retrainee strategy spans only a small section of the overall spectrum of entry points afforded retrainees, concentrating between 9 and 15 years TIS. This strategy is slightly different than recent recruiting patterns.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3																					
5																					
7																					
Total	1266	1263	1296	1319	1294	1278	1260	1249	1243	1233	1224	1223	1214	1205	1195	1186	1186	1185	1185	1185	1185

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 15. 4th Trial of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
Pipeline	1 year	60	60	60	60	60	59	60	60	60	58	60	60	60	50	55	47	37	36	32	60
Retrainee	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	8	8	8	8	6	8	8	8	8	8	7	4	3	8	7	8	0	8	8	8
	6 years	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
	7 years	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
	8 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
	9 years	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	7
	10 years	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	0	0
	11 years	0	24	0	0	6	0	3	3	4	19	12	8	13	11	9	13	24	24	24	24
	12 years	0	24	20	23	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	0
	13 years	14	0	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	0
	14 years	20	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	0
	15 years	14	0	14	14	14	14	14	14	14	2	11	14	14	14	14	14	14	14	14	14
	16 years	4	0	4	4	4	4	4	0	4	0	0	0	0	4	4	4	4	4	0	4
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Totals	90	97	100	94	99	95	98	95	98	97	99	95	99	105	102	108	120	120	120	96

Figure 16. Recruiting Strategy for 4th Trial

Figures 15 and 16 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 15 and 16 illustrate the results of placing the upper bounds listed in column 3 of Table 9 on the distribution of retrainees and applying a weight of 5 to the underachievement deviational variable associated with 5-level inventories and a weight of 2 to the overachievement deviational variable associated with 3-level inventories. A unit weight is applied to the remaining deviational variables. The objective of this weighting scheme is to force the model to prioritize the underachievement of 5-level inventories in order to bring them closer to their target value of 848 while also

prioritizing, to a smaller degree, the overachievement of 3-level inventories to bring them close to their target value of 123. If contracting career field managers decide to implement the recruiting strategy suggested in Figure 16, 3-level inventories increase to 303 in fiscal year plus 3 and stays there until fiscal years plus 19 and plus 20 where it declines to 299, 5-level inventories decrease and reach steady state at 352 in fiscal year plus 5 and 7-level inventories remain relatively stable and above 90% through fiscal year plus 20. Total inventories remains between 80% and 90% through fiscal year plus 20.

Figure 16 displays the recruiting strategy that achieves the inventory results displayed in Figure 15. The strategy calls for 60 pipeline accessions until fiscal year plus 14 where it begins declining to 32 in fiscal year plus 19, before spiking to 60 in fiscal year plus 20. These numbers are different than recent recruiting numbers. This retrainee strategy spans only a small section of the overall spectrum of entry points afforded retrainees, concentrating between 11 and 15 years TIS. This strategy still is different than recent recruiting patterns.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	1266	1280	1277	1306	1256	1245	1207	1197	1185	1190	1185	1193	1186	1185	1185	1185	1185	1185	1188	1185	1185

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 17. 5th Trial of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
Pipeline	1 year	48	60	60	53	60	49	60	48	60	46	54	41	55	43	45	28	24	21	57	60
Retrainee	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	0	0	5	8	3	8	8	7	0	0	0	4	0	0	0	8	0	8	0	8
	6 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
	7 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
	8 years	11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
	9 years	20	0	20	0	10	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
	10 years	24	17	18	0	24	4	0	24	20	20	10	0	0	0	0	0	10	1	0	0
	11 years	24	24	24	0	24	24	24	8	24	24	24	24	24	13	18	17	24	24	24	22
	12 years	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	0
	13 years	17	0	12	24	12	24	22	24	24	24	24	24	24	24	24	24	24	24	0	0
	14 years	0	0	0	19	0	0	0	0	0	0	14	20	20	20	20	20	20	20	20	0
	15 years	0	0	0	0	0	0	0	0	0	0	0	0	1	14	14	14	14	14	14	14
	16 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	0	4
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	120	65	104	75	98	84	94	87	92	92	96	97	93	96	101	112	120	120	83	88

Figure 18. Recruiting Strategy for 5th Trial

Figures 17 and 18 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 17 and 18 illustrate the results of placing the upper bounds listed in column 3 of Table 9 on the distribution of retrainees and applying a weight of 4 to the overachievement deviational variable associated with 7-level inventories and a weight of 2 to the underachievement deviational variable associated with 5-level inventories. A unit weight is applied to the remaining deviational variables. The objective of this weighting scheme is to force the model to prioritize the overachievement of 7-level inventories in order to bring them closer to their target value of 509 while also prioritizing, to a smaller degree, the underachievement of 5-level inventories the bring them close to their target value of 848. If contracting career field managers decide to implement the recruiting strategy suggested in Figure 18, 3-level inventories increase and reach steady state at 277 in fiscal year plus 2, 5-level inventories decrease and reach

steady state at 317 in fiscal year plus 5 and 7-level inventories remain relatively stable and above 90% through fiscal year plus 20. Total inventories stay between 80% and 90% through fiscal year plus 20.

Figure 18 displays the recruiting strategy that achieves the inventory results displayed in Figure 17. The suggested strategy calls for recruiting between 41 and 60 pipeline accessions each year except fiscal years plus 16 and plus 18, which calls for between 21 and 28. This is slightly different than recent recruiting numbers. This retrainee strategy again spans only a small section of the overall spectrum of entry points afforded retrainees, concentrating between 9 and 15 years TIS.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[redacted]																				
5																					
7																					
Total	1266	1292	1288	1316	1263	1245	1212	1196	1185	1185	1185	1198	1187	1240	1234	1254	1239	1224	1222	1185	1191

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 19. 6th Trial of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
Pipeline	1 year	60	11	52	16	46	19	47	29	37	33	60	0	60	6	60	60	60	60	0	60
Retrainee	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	0	19	18	36	36	36	36	36	36	36	36	36	36	36	36	36	36	24	36	36
	6 years	21	0	0	0	0	21	0	24	0	0	0	6	5	6	0	0	0	24	6	24
	7 years	24	24	24	6	6	0	0	0	6	0	0	0	0	0	0	0	0	0	0	24
	8 years	24	24	24	24	24	9	24	0	24	24	24	24	24	24	24	0	0	0	24	0
	9 years	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	0
	10 years	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	0	12	12	12	0
	11 years	12	12	12	12	12	12	12	12	12	12	0	12	12	12	12	12	12	0	12	12
	12 years	12	12	12	12	12	12	12	12	12	12	0	12	12	12	12	9	12	12	12	0
	13 years	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2	2	0
	14 years	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0
	15 years	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
	16 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	120	120	120	120	120	120	114	114	120	114	90	120	120	120	114	72	90	90	120	98

Figure 20. Recruiting Strategy for 6th Trail

Figures 19 and 20 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 19 and 20 illustrate the results of placing the upper bounds listed in column 4 of Table 9 on the distribution of retrainees and applying a unit-weighting scheme to the skill level inventories. If contracting career field managers decide to implement the recruiting strategy suggested in Figure 20, 3-level inventories remain relatively stable around 288 until fiscal year plus 19 and plus 20 when it declines to 256 and 266, respectively. 5-level inventories decrease to 296 in fiscal year plus 13 and fluctuates ending at 312 in fiscal year plus 20. 7-level inventories remain relatively stable and above 90% through fiscal year plus 20. Total inventories also remain stable and between 80% and 90% through fiscal year plus 20.

Figure 20 displays the recruiting strategy that achieves the inventory results displayed in Figure 19. The strategy is a result of optimizing inventory levels while applying upper bounds to recruiting numbers, upper bounds to the retrainee distribution, and lower bounds to total inventories. The number of pipeline accessions suggested in this strategy fluctuates throughout the 20-year period; it ranges from 0 in fiscal years plus 12 and plus 19 to 60 in eight of the 20 fiscal years. This strategy is significantly different from current recruiting numbers. This retrainee strategy spans only a section of the overall spectrum of entry points afforded retrainees, concentrating between 5 and 12 years TIS. This is similar to recent recruiting patterns.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	+20
3																					
5																					
7																					
Total	1266	1292					1325	1307	1304	1306	1310									1330	1205

NOTE: The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 21. 7th Trial of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
Pipeline	1 year	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	0	37
Retrainee	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	0
	6 years	24	6	6	24	6	0	0	0	0	6	6	6	6	6	6	6	24	24	0	0
	7 years	0	0	0	0	0	8	6	6	6	0	0	0	0	0	0	0	0	0	0	0
	8 years	6	24	24	6	24	24	24	24	24	24	24	24	24	24	24	24	6	0	0	0
	9 years	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	0
	10 years	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0
	11 years	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	12 years	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	0
	13 years	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0
	14 years	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	2	2	0
	15 years	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
	16 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	114	78	12

Figure 22. Recruiting Strategy for 7th Trail

Figures 21 and 22 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 21 and 22 illustrate the results of placing the upper bounds listed in column 4 of Table 9 on the distribution of retrainees and applying a weight of 4 to the underachievement deviational variable associated with 5-level inventories. A unit weight is applied to the remaining deviational variables. The objective of this weighting scheme

is to force the model to prioritize the underachievement of 5-level inventories in order to bring them closer to their target value of 848. If contracting career field managers decide to implement the recruiting strategy suggested in Figure 22, 3-level inventories increase to 342 in fiscal year plus 3 and stay there until fiscal year plus 18 where it begins declining to 123 in fiscal year plus 20, 5-level inventories decrease to 376 and remain relatively stable at around 380 through fiscal year plus 20 and 7-level inventories increase and remain above 90% through fiscal year plus 20. Total inventories fluctuate between marginal manning and above 90% manning.

Figure 22 illustrates the recruiting strategy that achieves the inventory results displayed in Figure 21. The strategy is a result of optimizing inventory levels while applying upper bounds to recruiting numbers, upper bounds to the retrainee distribution, and lower bounds to total inventories. The suggested pipeline recruiting strategy calls for 60 pipeline accessions each year except the last two years. This is similar to current recruiting numbers. This retrainee strategy spans only a section of the overall spectrum of entry points afforded retrainees, concentrating between 5 and 12 years TIS. This is also similar to recent recruiting patterns.

Skill Level	Current Fiscal Year	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	1266	1292	1288	1316	1263	1245	1212	1196	1185	1185	1185	1185	1185	1219	1222	1198	1222	1189	1192	1185	1185

<u>NOTE:</u> The color coding in the figure represents the following: red indicates under 80% manned, yellow indicates between 80% and 90% manned and green indicates over 90% manned.

Figure 23: 8th Trial of Optimization Model

	TIS	FY +1	FY +2	FY +3	FY +4	FY +5	FY +6	FY +7	FY +8	FY +9	FY +10	FY +11	FY +12	FY +13	FY +14	FY +15	FY +16	FY +17	FY +18	FY +19	FY +20
Pipeline	1 year	60	11	52	16	46	19	47	29	60	60	40	13	47	60	6	60	60	60	13	60
Retrainees	4 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 years	0	19	18	36	36	36	36	36	36	21	36	36	36	36	36	36	36	36	18	36
	6 years	21	0	0	0	0	21	0	24	7	0	0	6	6	0	6	0	24	24	24	24
	7 years	24	24	24	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	24	24
	8 years	24	24	24	24	24	9	24	0	24	24	24	24	24	24	24	24	0	0	0	1
	9 years	12	12	12	12	12	12	12	12	0	12	12	12	12	0	12	12	0	12	12	0
	10 years	12	12	12	12	12	12	12	12	0	12	0	12	12	12	12	12	12	12	12	0
	11 years	12	12	12	12	12	12	12	12	12	12	12	12	12	0	12	12	0	7	12	12
	12 years	12	12	12	12	12	12	12	12	12	0	12	12	12	0	12	12	0	12	12	0
	13 years	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2	0
	14 years	1	2	2	2	2	2	2	2	2	2	0	2	2	2	2	2	0	2	2	0
	15 years	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
	16 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	120	120	120	120	120	120	114	114	97	88	100	120	120	78	120	114	72	109	120	98

Figure 24. Recruiting Strategy for 8th Trail

Figures 23 and 24 are the result of optimizing skill level inventories with the parameters listed in Tables 6 through 8 and 9 through 11 and the constraints discussed above. Figures 23 and 24 illustrate the results of placing the upper bounds listed in column 4 of Table 9 on the distribution of retrainees and applying a weight of 5 to the underachievement deviational variable associated with 5-level inventories, a weight of 3 to the overachievement deviational variable associated with 3-level inventories and a weight of 2 to the overachievement deviational variable associated with the 7-level inventories. A weight of one is applied to the remaining deviational variables. The objective of this weighting scheme is to force the model to prioritize the underachievement of 5-level inventories in order to bring them closer to their target value of 848 while also prioritizing, to a smaller degree, the overachievement of both the 3- and 7-level inventories bringing them close to their respective target values of 123 and 509.

If contracting career field managers decide to implement the recruiting strategy suggested in Figure 24, 3-level inventories fluctuate some but remain relatively constant at around 288, 5-level inventories fluctuate before decreasing as low as 277 in fiscal year plus 17 before ending at 303 in fiscal year plus 20 and 7-level inventories remain stable and above 90% through fiscal year plus 20. Total inventories also remain stable and between 80% and 90% through fiscal year plus 20.

Figure 24 illustrates the recruiting strategy that achieves the inventory results displayed in Figure 23. The strategy is a result of optimizing inventory levels while applying upper bounds to recruiting numbers, upper bounds to the retrainee distribution, and lower bounds to total inventories. The number ofpipeline accessions suggested in this strategy fluctuates throughout the 20-year period; it ranges from 11 in fiscal years plus 2 to 60 in 8 of the 20 fiscal years. This strategy is significantly different from current recruiting numbers. This retrainee strategy spans only a section of the overall spectrum of entry points afforded retrainees, concentrating between 5 and 12 years TIS. This is similar to recent recruiting patterns.

The optimization model selects the number of recruits to bring in, when to bring them in and where to bring them in within the boundaries established by the constraints in the model. Constraints are selected in a manner that allows flexibility for generating solutions. In many of the solutions shown above it appears that the retrainee distribution is following the upper bounds placed on the distribution, but keeps in mind that there are many unused cells available to recruit retrainees.

Cross analysis of the Optimization model

In this section, the optimization results are examined in groups to identify and analyze trends in the data. The first optimization trial was done simply to demonstrate the effects of not applying upper bounds on the distribution of retrainees. The next four trials use upper bounds on the distribution of retrainees and weights on the skill level inventories. The upper bounds were selected in an attempt to represent recent recruitment patterns. The weighting schemes were selected at random to demonstrate the capability of the model. The last three trials use a different set of upper bounds for the retrainee distribution. This set of upper bounds represents the career field managers preferred retrainee recruitment strategy. The weighting schemes for this set of results were also selected at random to demonstrate the capability of the model.

While analyzing the first group of solutions, Figures 11 through 18, the first and most visible trend deals with the type of retrainees the model selects. In all 4 instances, the vast majority of retrainees have between 9 and 15 years TIS. Bringing in retrainees earlier in the model would cause a significant over manning in the 7-skill level inventories. This problem occurs because retrainees upgrade to a 7-skill level very quickly and remain at the 7-skill level for a very long time. The vast majority remains in the 7-skill level until they retire from the Air Force.

When examining these four trials together it becomes apparent that the weighting schemes do have a significant impact on the results. The weight schemes do not cause any of the skill level inventories to cross any of the established manning boundaries but it does bring them significantly closer to there target values. One reason the weighting scheme did not cause movement above or below the established skill level boundaries is

because the 3- and 7-level inventories start out and remain above the 90% manning level for the entire time period while the 5-level inventories start out and remain far below the 80% manning level for the entire time period. Considering trials 2 through 5, the weighting scheme used in Figures 15 and 16, a weight of 5 on the underachieving variable for 5-levels and a weight of 2 on the overachieving variable of 3-levels, provides the most balanced solution. This solution only considers the weights selected in the first four trials. Contracting career field managers have the knowledge and experience to apply a more appropriate and meaningful weighting scheme.

The last observation made on the first four trials is the difference in recruiting numbers. The second trial, Figures 11 and 12, required relatively few pipeline personnel but almost the maximum number of retrainees. This occurred because no weights are applied to the 5-skill level. Recruiting more pipeline accessions helps increase 5-level inventories while recruiting more retrainees helps increase 7-level inventories. The remaining three models in this section show a significant increase in the number of pipeline accessions because of the weights applied to the 5-level underachievement variable. Trials 2 and 3 have much fewer retrainees than trials 4 and 5.

Trials 6, 7, and 8 are used to examine the consequences of bringing in retrainees earlier in their careers. In these three trials, Figures 19 through 24, the majority of retrainees enter the model with between 5 and 12 years TIS as opposed to between 9 and 15 years TIS. This occurs because the upper bounds, placed on the retrainee distribution, get significantly tighter as TIS increases. These upper bounds are forcing the model to bring in retrainees early in their careers. The inventory results in these three trials appear to be very similar to the inventory results in the first set of trials.

The other difference, between the two sets of trials, is the number of accessions. Both pipeline and retrainee recruitment numbers were higher in the last three trials when compared to the aforementioned set of trials. One reason for this increase in accessions is the higher loss rates associated with individuals having 5,6,7, and 8 years TIS. All retrainees entering the career field with between 5 to 8 years TIS must pass through some of the largest loss rates in the career field. Once retrainees enter the model they follow the same transition rates as the others already in the model.

Summary

The three manpower models discussed above are powerful tools, which provide valuable information for making recruiting and retention decisions. The results shown above illustrate the significant capabilities of the DSS. The models are very flexible and easy to use. They allow career field managers to make changes based on priorities and to observe the impact of those priorities on skill level inventories.

The manpower modeling results shown in this chapter helped demonstrate manpower inventory trends. The deterministic model illustrated how the two categories of recruits--pipeline and retrainees--affect the skill level inventories. The trend shows that as the number of retrainee recruits increases and the number of pipeline accessions decrease, the 7-skill level inventories increase and the 5-skill level inventories decrease. The opposite is also true as the number of pipeline accessions increase and the number of retrainees decrease the 5-skill level inventories increase and the 7-skill level inventories decrease. The stochastic model identified the effects of variable loss rates on skill level inventories. The model illustrates that different loss rates do not significantly affect skill

level inventories in accordance with the current manning requirements. It also confirmed that as skill level increases and the model approaches fiscal year plus 20 the variability also increases. The optimization model provides a detailed recruiting strategy based on given criteria. The model allows the user to apply constraints and weights to make the solution more realistic. The optimization model illustrates that applying weights to the model has a significant affect on the skill level inventories. It also illustrates the differences between recruiting retrainees early in their career as opposed to later in their careers. While the results were similar, recruiting retrainees later in their careers provided slightly better results and required fewer recruits. The reason it requires fewer recruits is because the loss rates are much lower after 8 years TIS.

All three manpower models indicate a severe manning shortage in the 5-skill level that will continue unless something is done to correct the problem. Some possible solutions are:

1. Recruit a much larger number of pipeline accessions, which would cause serious over manning in the 7-skill level and total inventories.

2. Shift some of the 5-skill level manpower authorizations to the 3- and 7-skill levels.

3. Adjust skill level time lines to keep retrainees in the 5-skill level longer.

This chapter demonstrates the capabilities of these manpower models in providing a great deal of valuable manpower planning information.

V. Conclusions and Recommendations

Overview

This research effort supports the development of a DSS for contracting career field mangers. The DSS is made up of three manpower models: a deterministic model, a stochastic model and an optimization model. *(The three manpower models that make up the DSS are on the CD attached to the inside cover of this thesis. The software requirements are listed on the DTIC Form 530 at the end of this document just preceding the SF Form 298.)* Conclusions and recommendations where reached through the implementation of each model. The models are based on manpower data provided by several Air Force organizations and parameters selected by the researcher. There may be certain DoD and/or Air Force policies that make some of the recommendations infeasible; in that case DoD and/or Air Force policy takes precedence.

Research Objective

The primary objective of this research was to develop a user-friendly decision support system for contracting career field managers to use when making recruiting and retention decisions. The second objective was to provide a modeling tool that would forecast steady state skill level inventories based on current and alternative recruiting strategies. The third objective was to provide a tool that would allow career field managers to analyze the effects that variable loss rates have on skill level inventories. The last objective was to provide a tool to generate recruiting schedules based on the career field managers input. These objectives have been meet with the three manpower models that make up the decision support system developed in this thesis.

Relevancy of the Research

This research effort fills a gap in Air Force manpower modeling. The DSS developed for this thesis provides contracting career field managers with their first set of manpower models to help analyze and manage the career field's manpower inventories. These models are also the first and only manpower models in the Air Force that track skill level inventories. Having the right skill level mix is critical to accomplishing the contracting career field's mission. This DSS is a powerful tool for contracting career field managers and is a valuable addition to the Air Force's manpower modeling inventory. The Air Force Personnel Operations Agency has expressed interest in making these skill level inventory models available to all career field managers in the Air Force.

Summary of Research

The DSS provides valuable manpower information to assist contracting career field managers in making recruiting and retention decisions. Each model in the DSS serves a different purpose and provides critical information about the contracting career field's skill level inventories. Analyzing the results of all three manpower models provides career field managers with a thorough analysis of the primary elements involved in building and maintaining their skill level inventories.

The deterministic model displays current and predicts future skill level inventories based on the career field managers input. This model allows career field managers to assess the impact of recruiting the same number and mix of personnel over the next 20 years. The model also allows career field managers to run "what if" analyses, based on

different recruiting numbers and different recruiting mixes, to gain a better understanding of how those changes affect the career field's skill level inventories.

The stochastic model is very similar to the deterministic model but its purpose is to analyze the effects of variable loss rates. The model is used to run simulations based on a triangular distribution using plus or minus 15 percent of FY2000 loss rates. These values were provided by AFPOA/DPY and cover all loss rates encountered in the last two decades including the reduction in force in the early 1990's. The model also provides a great deal of statistical information including the probabilities associated with each possible inventory outcome. This probabilistic ability serves as a risk assessment tool to help identify the probabilities associated with exceeding or falling short of certain inventory targets.

The optimization model is a linear programming model used to generate recruiting schedules. The model selects the optimal recruiting schedule while considering the available resources, manpower priorities and current constraints. The model also displays the inventory results of implementing each recruiting strategy. The model allows career field managers to adjust skill level weighting and resource constraints to match the career field's current situation.

Findings

After completing multiple trials and simulations on each of the three manpower models there were several trends that became apparent. These trends make up the findings of this research effort and are listed below.

Deterministic Model

The first finding deals with the number of pipeline and retrainees that are recruited each year. As the number of pipeline accessions increase and the number of retrainees decrease the 5-level inventories increase and the 7-level inventories decrease. The opposite is also true, as the number of pipeline accession decrease and the number of retrainees increase the number of 7-levels increase and the number of 5-levels decrease. This occurs because retrainees pass through the 5-skill level very quickly and stay in the 7-skill level for many years whereas pipeline accessions spend more time in the 5-skill level before upgrading to the 7-skill level. The reason pipeline accessions take longer to upgrade to a 7-skill level is because they must wait until they are promoted to SSgt before beginning 7-level training whereas most retrainees are SSgt's when they enter the career field.

The severe shortage of 5-skill level personnel is the most critical finding in the deterministic model. Within current manpower constraints there does not appear to be any combination of recruits that would bring 5-level inventories in line with 5-level manpower authorizations. The only way to bring 5-level inventories in line would be to recruit more than 275 pipeline accessions each year for 20 years and no retrainees. This would bring 5-level inventories above the 80% level by fiscal year plus 8. The problem then becomes the 7-level inventories, while 5-level inventories increase above 80% the 7-level inventories drop below 80%. The best strategy is to keep an equal mix of pipeline accessions and retrainees, which will maintain 7-skill level inventories over 90% while slightly increasing the steady state of the 5-skill level inventories. It is evident that if the

recruitment numbers remain stable in the contracting career field, the shortages in the 5-skill level inventories will continue.

Stochastic Model

The primary finding in the stochastic model is that variable loss rates do not significantly impact the current skill level inventories in accordance with the current recruiting and retention initiatives. This model will play a more important role if changes are made to bring manpower authorizations more in line with actual skill level inventories.

Optimization Model

The finding in the Optimization model is to recruit retrainees later in their careers. The reason for recruiting retrainees later in their careers is to avoid the high loss rates experienced in years 4 through 8. If career field managers decide to recruit retrainees earlier in their careers they would have to recruit larger numbers of them to offset the higher loss rates. The benefit of recruiting retrainees with more than 8 years TIS is based on the current trend that once an enlisted member commits beyond 8 years TIS they remain in the Air Force and in the career field until they reach 20 years TIS or more.

Recommendations

The following recommendations are based on the aforementioned findings. The feasibility of the recommendations will be addressed by contracting career field managers. The recommendations focus on balancing the skill level inventories of the contracting enlisted force. The largest issue involves the severe manpower shortages in the 5-skill level inventories. These shortages have been around since the reduction in

force in the early 1990's. Equally noteworthy is that the other skill levels have been over manned during this time, which enabled the career field to balance the 5-level demand. Career field managers have made it clear that the career field can successfully accomplish its mission with the 5-skill level shortages as long as there are enough 7-skill level personnel to compensate for those shortages.

The first recommendation addresses the skill level imbalance by recruiting a larger number of pipeline accessions and a smaller number of retrainees. A greater number of pipeline accessions will increase 5-level inventories because of their longer training requirements. The only shortcoming in pursuing this strategy is that it decreases 7-skill level and total inventories because, similarly, pipeline accessions take longer to upgrade to the 7-skill level and their retention rates are lower than retrainees.

The second recommendation involves increasing pipeline accessions while maintaining cross training manning initiatives. This recommendation would increase 5-skill level inventories and maintain 7-skill level and total inventories at above acceptable levels. Implementing this strategy, however, would further increase the already severe overages in the 3-skill level and increase the 7-skill level inventory above 100%. To compensate for this, career field managers would have to realign manpower authorizations to reflect the adjusted 3- and 7-skill level inventories.

The third recommendation adjusts the skill level upgrading timelines to cause retrainees to serve as a 5-skill level for a longer period of time. This would increase the 5-level inventories again, but at the expense of the 7-skill level inventories.

The fourth recommendation adjusts the contracting career fields skill level manpower authorizations to more closely match the current skill level inventories. The career field

has been successfully carrying out the mission with relatively the same inventory levels over the last 10 years. Adjusting the manpower authorization would involve distributing a portion of the 5-level authorizations to the 3- and 7-level authorizations.

The last and most promising recommendation is to offer an incentive that would lower the loss rate of first term enlistees. Their loss rate at 4-year TIS is the largest loss rate in the contracting career field and is nearly 50%. Of all the recommendations, reducing the loss rate at 4 years TIS to 25% has the largest effect on balancing the skill level inventories. The difficulty with this strategy involves offering a desirable enough incentive to decrease the loss rate by 25%.

Recommendations for Future Research

This research effort identifies many opportunities for future research. The first is developing similar models to monitor the contracting career field's officer force. If officer manpower models were added, the DSS would cover all contracting manpower resources. Another area for future research involves developing models to assign contracting personnel to positions based on skill level and manning priorities. This would have a huge impact on the career field's manning effectiveness. Finally, some qualitative opportunities relating to how to improve recruitment and retention rates, how to correct the imbalance among skill level inventories and how to coordinate the efforts of career field managers with those of AFPC assignments personnel exist. Answers to these research issues would help improve manpower effectiveness and efficiency.

Model Strengths

The greatest strength of the DSS is its ability to provide career field managers with an in depth analysis of skill level inventories which will lead to more informed recruiting and retention decisions. The models are very user-friendly and capable of being adjusted to meet current priorities and constraints. The models provide nearly instantaneous results allowing career field managers to generate the required information in a matter of minutes. These models are easily adaptable to other career fields in the Air Force.

Model algorithms were verified by applying common parameters to each of the three manpower models, which generated identical results. For example, recruiting strategies generated in the optimization model were used as input to the deterministic model. Also, loss rates generated in the stochastic model were used as input to the deterministic model. All models generated identical results when using the same parameters.

Model Limitations

The major limitation of the decision support system was the inability to validate the models due to the lack of skill level inventory data. Validation will occur over the next several years by using the model and comparing projected against actual inventories.

The next limitation deals with the late model effects that occur in the optimization model. Since the optimization model is based on a Markovian process it has difficulty generating realistic solutions towards the end of the model. The reason it has difficulty is because the Markovian process is a continuous process, ending the model abruptly causes

the model to recruit fewer, and, in some cases, no additional personnel in the last few years.

Another limitation deals with the weighting schemes used in the model. When multiple weights are applied, the largest weights usually have the most effect on the model. There are some instances where the weight is to small to overcome a significant under- or over-manning situation, making the weighted variable a second level priority. This occurs because some skill levels, like the 5-skill level, are extremely over- or under-manned, which forces the model to continue minimizing that difference until the weights applied to other priorities are large enough to override it. This highlights the importance of selecting an appropriate weight to meet the career field's objectives.

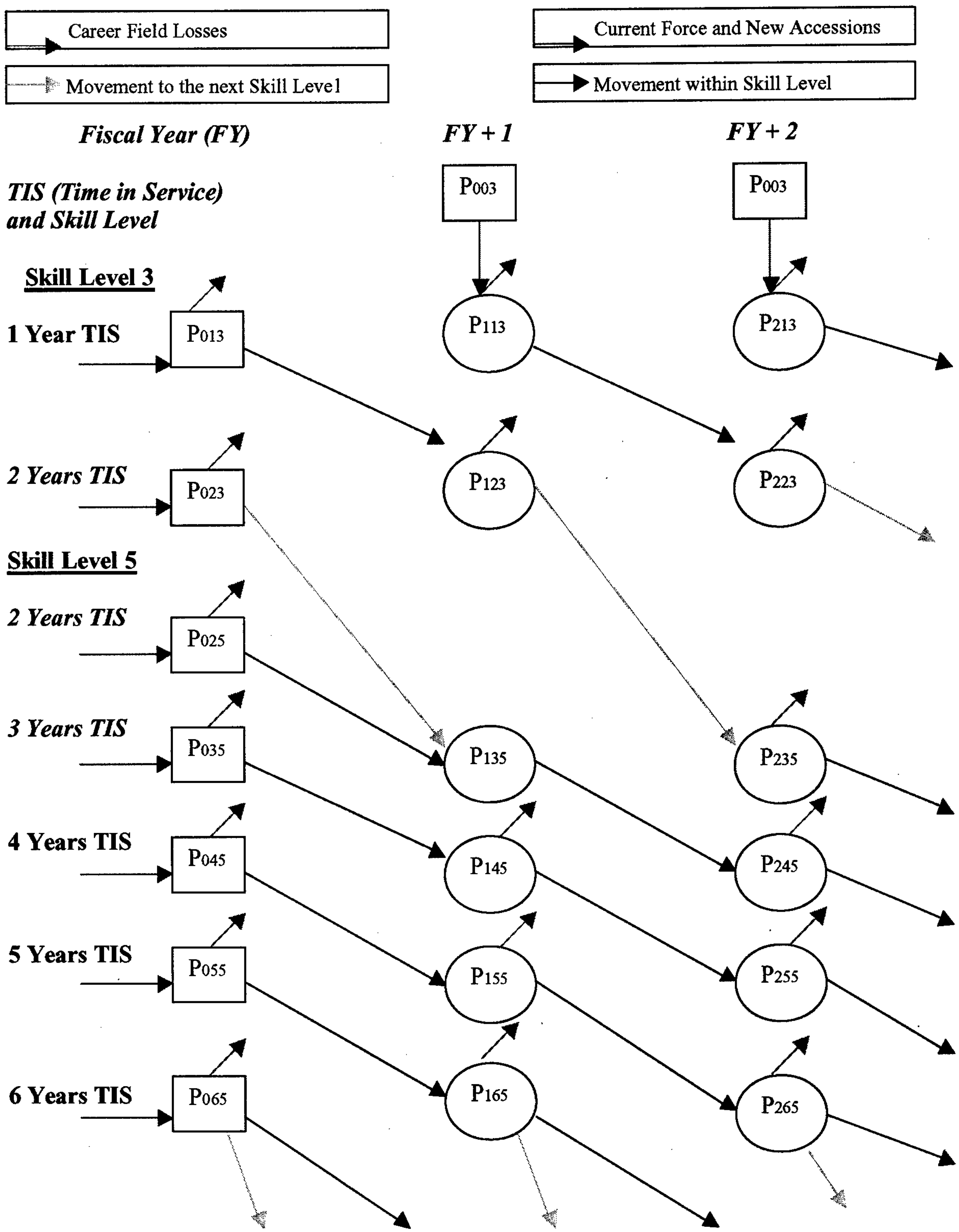
Which skill level the weight is applied to also has a significant affect on the model. Placing weights on the 3- and 5-level deviational variables has a more positive impact on inventory results then placing weights on the 7-level deviational variables. This occurs because of the way the model is designed. The optimization model is a linear programming model overlaying a Markovian network flow model. Applying weights to the 3- and 5-level variables allow the model to follow its natural flow, which involves pushing inventory changes through the Markovian network flow. Weights applied to the 7-level variables work against the natural flow by forcing the model to pull people through the 3- and 5-level inventories in order to affect the 7-level inventories.

Conclusion

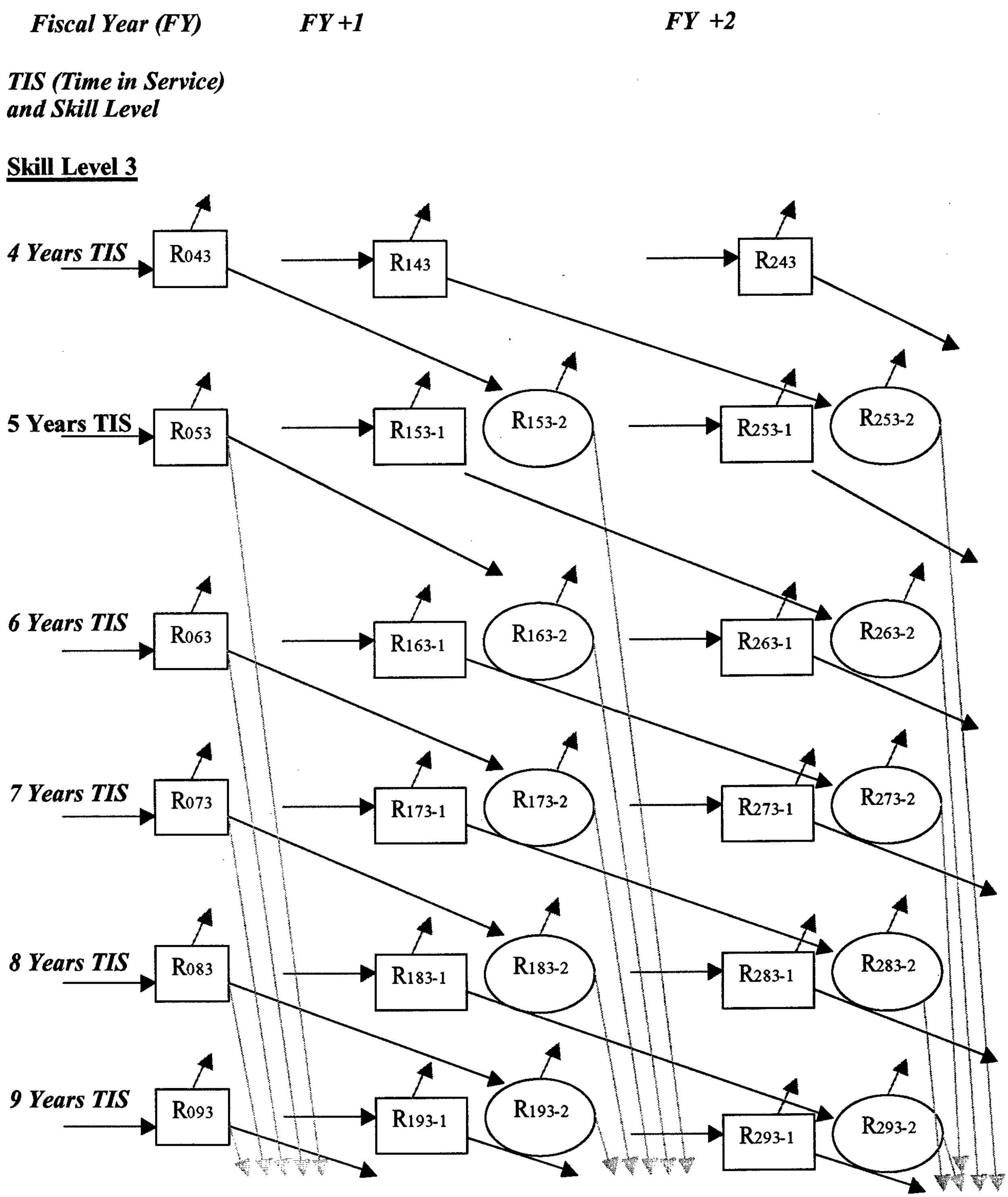
The decision support system developed in this thesis is a valuable asset for contracting career field managers. The tools that make up the decision support system

allow career field managers to perform an in depth analysis of the career field's skill level inventories. This analysis provides the information necessary to make more informed recruiting and retention decisions as well as supporting or debating recruiting and retention policies. These models could ultimately save the DoD and the Air Force a great deal of time and money by more accurately recruiting and retaining the right number and mix of personnel.

Appendix A. Network Flow of Pipeline Accessions



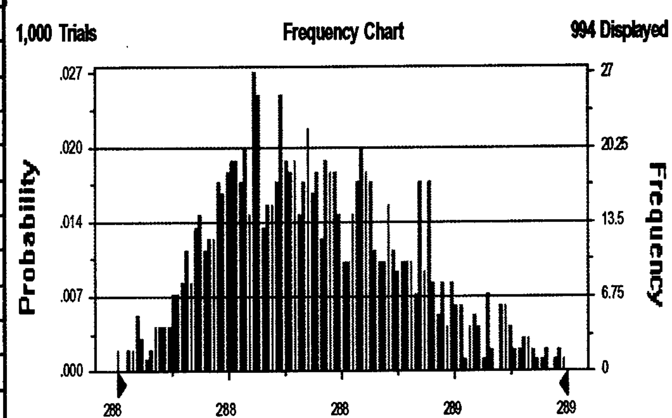
Appendix B. Network Flow of Retrainees



Appendix C. Simulation reports on the Stochastic Model

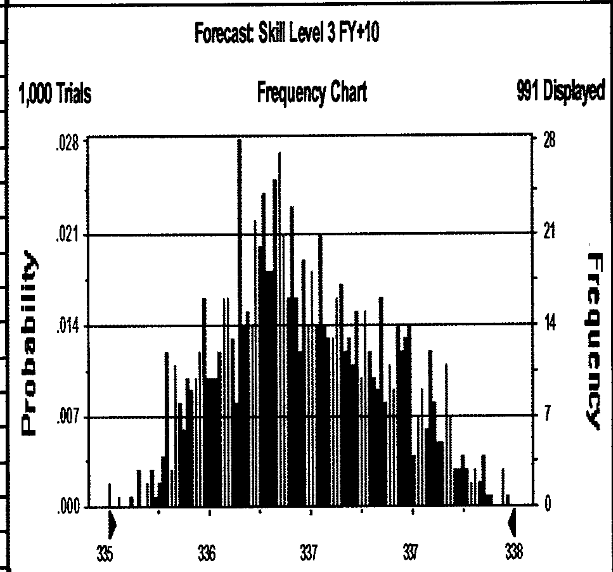
	Crystal Ball Report	
	Simulation started on 1/27/02 at 17:46:45	
	Simulation stopped on 1/27/02 at 17:47:21	
Summary:		
Display Range is from 288 to 289		
Entire Range is from 288 to 289		
After 1,000 Trials, the Std. Error of the Mean is 0		
Statistics:		**Value**
Trials		1000
Mean		288
Median		288
Standard Deviation		0
Variance		0
Skewness		0.34
Kurtosis		2.62
Coeff. of Variability		0.00
Range Minimum		288
Range Maximum		289
Range Width		1
Mean Std. Error		0.01

Percentile	Value
0%	288
10%	288
20%	288
30%	288
40%	288
50%	288
60%	288
70%	288
80%	288
90%	289
100%	289



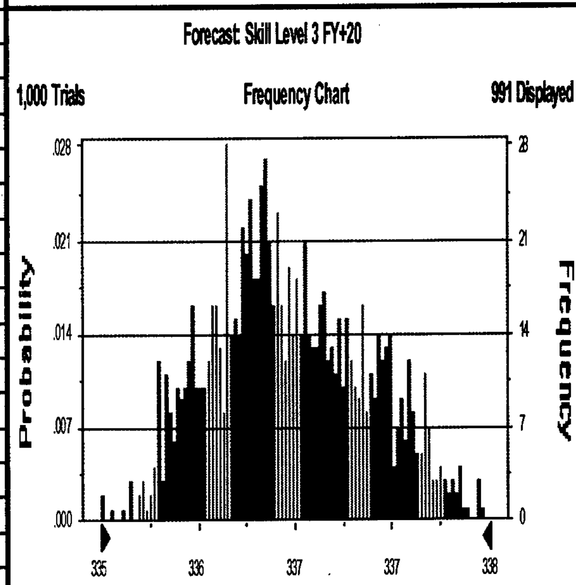
Display Range is from 335 to 338	
Entire Range is from 335 to 338	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	337
Median	337
Standard Deviation	1
Variance	0
Skewness	0.33
Kurtosis	2.70
Coeff. of Variability	0.00
Range Minimum	335
Range Maximum	338
Range Width	3
Mean Std. Error	0.02

Percentile	Value
0%	335
10%	336
20%	336
30%	336
40%	336
50%	337
60%	337
70%	337
80%	337
90%	337
100%	338



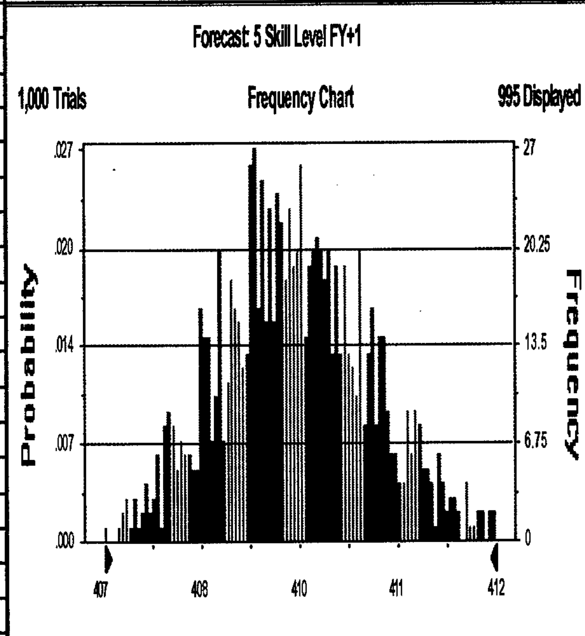
Display Range is from 335 to 338	
Entire Range is from 335 to 338	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	337
Median	337
Standard Deviation	1
Variance	0
Skewness	0.33
Kurtosis	2.70
Coeff. of Variability	0.00
Range Minimum	335
Range Maximum	338
Range Width	3
Mean Std. Error	0.02

Percentile	Value
0%	335
10%	336
20%	336
30%	336
40%	336
50%	337
60%	337
70%	337
80%	337
90%	337
100%	338



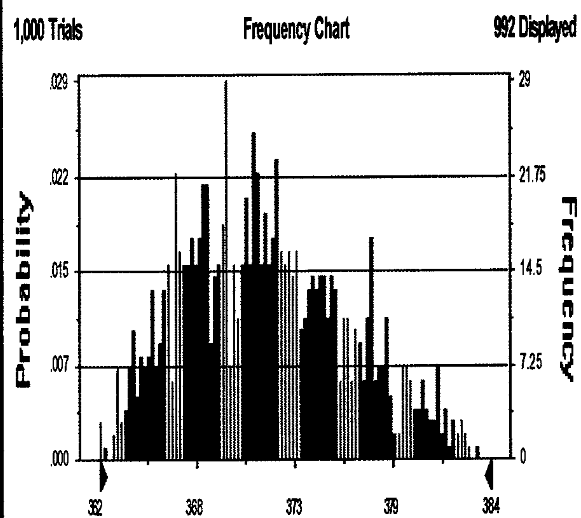
Display Range is from 407 to 412	
Entire Range is from 407 to 413	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	410
Median	410
Standard Deviation	1
Variance	1
Skewness	0.20
Kurtosis	2.84
Coeff. of Variability	0.00
Range Minimum	407
Range Maximum	413
Range Width	6
Mean Std. Error	0.03

Percentile	Value
0%	407
10%	408
20%	409
30%	409
40%	409
50%	410
60%	410
70%	410
80%	410
90%	411
100%	413



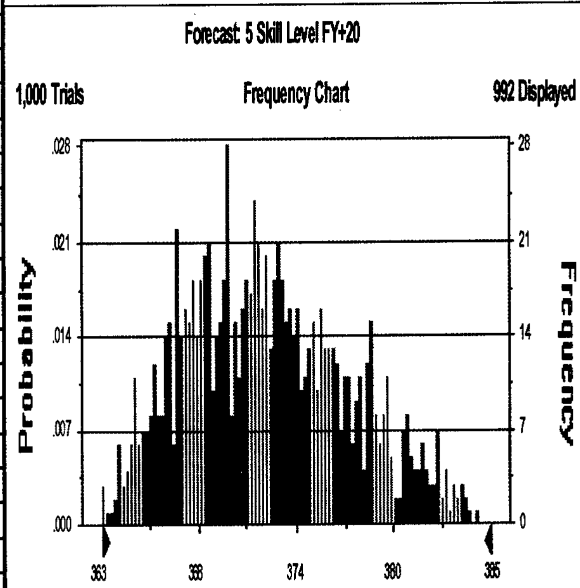
Display Range is from 362 to 384	
Entire Range is from 361 to 387	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	372
Median	371
Standard Deviation	5
Variance	23
Skewness	0.35
Kurtosis	2.57
Coeff. of Variability	0.01
Range Minimum	361
Range Maximum	387
Range Width	26
Mean Std. Error	0.15

Percentile	Value
0%	361
10%	366
20%	367
30%	368
40%	370
50%	371
60%	372
70%	374
80%	376
90%	378
100%	387



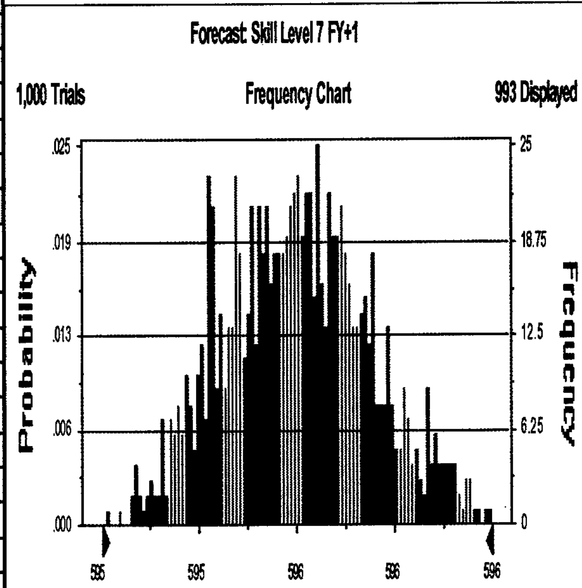
Display Range is from 363 to 385	
Entire Range is from 362 to 388	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	372
Median	372
Standard Deviation	5
Variance	23
Skewness	0.35
Kurtosis	2.57
Coeff. of Variability	0.01
Range Minimum	362
Range Maximum	388
Range Width	27
Mean Std. Error	0.15

Percentile	**Value**
0%	362
10%	366
20%	368
30%	369
40%	371
50%	372
60%	373
70%	375
80%	377
90%	379
100%	388



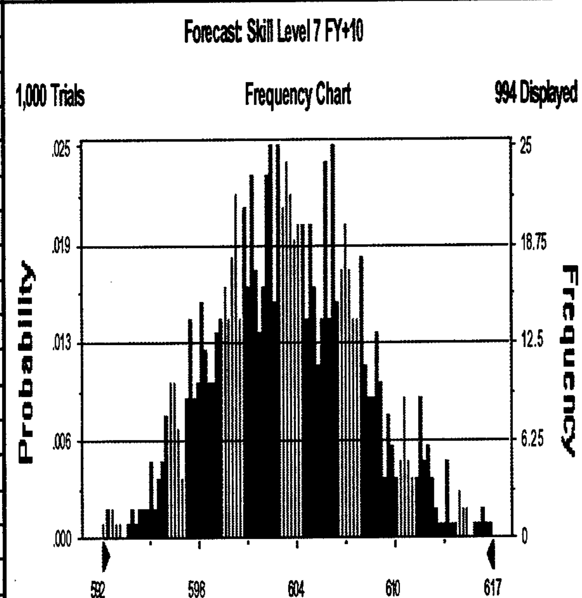
Display Range is from 595 to 596	
Entire Range is from 595 to 597	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	596
Median	596
Standard Deviation	0
Variance	0
Skewness	0.10
Kurtosis	2.73
Coeff. of Variability	0.00
Range Minimum	595
Range Maximum	597
Range Width	2
Mean Std. Error	0.01

Percentile	Value
0%	595
10%	595
20%	595
30%	595
40%	595
50%	596
60%	596
70%	596
80%	596
90%	596
100%	597



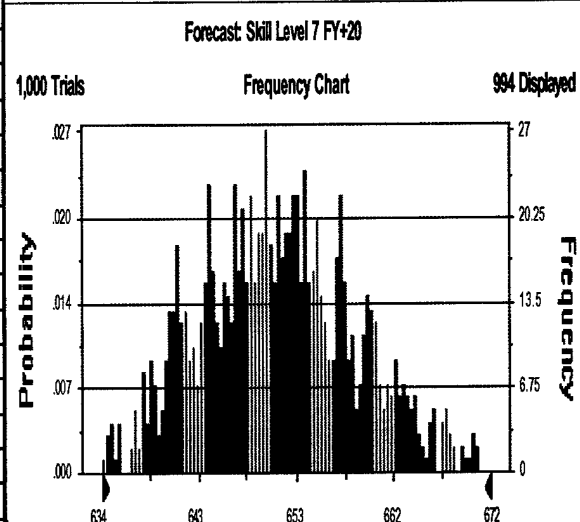
Display Range is from 592 to 617	
Entire Range is from 590 to 620	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	604
Median	603
Standard Deviation	5
Variance	23
Skewness	0.18
Kurtosis	2.85
Coeff. of Variability	0.01
Range Minimum	590
Range Maximum	620
Range Width	30
Mean Std. Error	0.15

Percentile	Value
0%	590
10%	597
20%	599
30%	601
40%	602
50%	603
60%	605
70%	606
80%	608
90%	610
100%	620

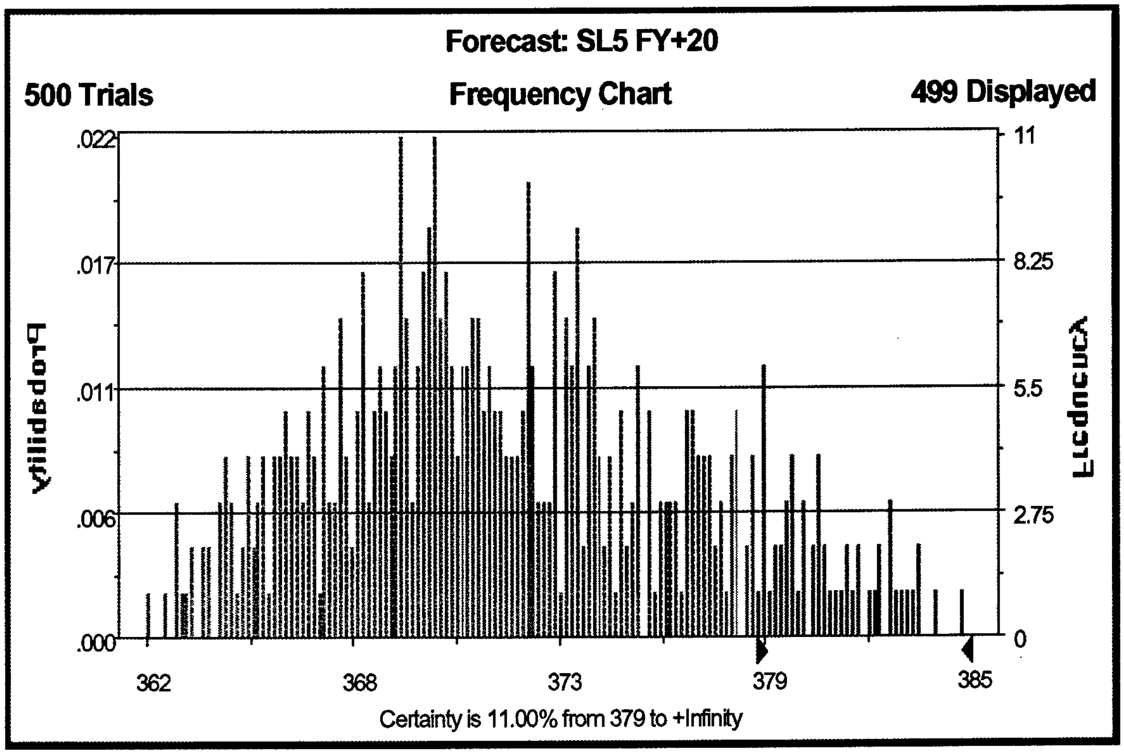


Display Range is from 634 to 672	
Entire Range is from 631 to 679	
After 1,000 Trials, the Std. Error of the Mean is 0	
	Value
Trials	1000
Mean	651
Median	651
Standard Deviation	8
Variance	59
Skewness	0.22
Kurtosis	2.74
Coeff. Of Variability	0.01
Range Minimum	631
Range Maximum	679
Range Width	48
Mean Std. Error	0.24

Percentile	Value
0%	631
10%	641
20%	644
30%	647
40%	649
50%	651
60%	653
70%	655
80%	658
90%	661
100%	679



Appendix D. Frequency Chart



The frequency chart displayed above is a risk assessment tool that allows career field managers to quickly and easily identify the probabilities associated with exceeding or falling short of inventory targets. Frequency charts are available for each forecast cell. The probabilities are displayed by sliding either arrow to the corresponding threshold being investigated. As depicted above, as the arrow moves right the frequency chart turns red identifying those outcomes that are below the arrow. For example, in the chart above the arrow was moved to 379 where the probability of the skill level inventory exceeding 379 is 11% and the probability that the skill level inventory will be below 379 is 89%.

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Vita

Captain Larry D. Mercier Jr. was born in Manchester, New Hampshire. After graduating from Berlin High School, Berlin, New Hampshire in 1986, he joined the United States Air Force as a Transportation Specialist. While serving in the Transportation career field he was assigned to Kunsan AFB, South Korea, Plattsburgh AFB, Plattsburgh, New York, Daharan AB, Saudia Arabia, and Malmstrom AFB, Great Falls, Montana. These assignments spanned 9 years and during that time, then SSgt Mercier received two Associate Degree's, one from the Community College of the Air Force in Transportation Management and one from Clinton Community College, Plattsburgh, New York, in Business Administration. After serving 9 years as an enlisted member of the Air Force, SSgt Mercier decided to seek a commission in the Air Force. He left the Air Force in August of 1995 and joined the ROTC Detachment at Montana State University where he earned a Bachelor's Degree in Business Management. Upon graduating in May 1997, he received his commission in the United States Air Force. Following his first assignment at Hill AFB, Utah, he entered the Master's program at the School of Engineering and Management, Air Force Institute of Technology, in August 2000.

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A GENERALIZED DECISION SUPPORT SYSTEM FOR THE CONTRACTING CAREER FIELD

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27. Abstract: This research effort develops a generalized decision support system (DSS) to assist contracting career field managers in making recruiting and retention decisions. The DSS focuses on the skill level inventories of the contracting enlisted force. The interest in this research was identified by contracting career field managers due to the recent negative trends in recruitment and retention and the lack of analytical tools available. To accomplish this objective, manpower models were developed using a combination of techniques gathered through interviews with Army and Air Force analysts and a literature review focusing on manpower modeling. The models developed in this study are intended to assist career field managers in recruiting and					
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